Forth Replacement Crossing – Local Area Modelling Audit Report

Transport Scotland

Final Audit Report – Final

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FORTH REPLACEMENT CROSSING – LOCAL AREA S-PARAMICS MODELLING AUDIT REPORT

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EXECUTIVE SUMMARY

SIAS Limited (SIAS), as part of the Transport Scotland's Traffic and Transport Advisor and Auditor (TTAA) commission, has undertaken a review of the Jacobs-Arup joint venture local area S-Paramics modelling associated with the traffic, economic and environmental assessment of the Forth Replacement Crossing (FRC).

The local area modelling was based on the development and application of an S-Paramics microsimulation model. The area covered by the local area model was primarily confined to the Forth Crossing corridor.

The primary objectives of the local area S-Paramics models can be summarised as follows:

- *Operational Assessment:* the models are to be used to assess the more detailed operational aspects of the proposed scheme including the Active Traffic Management (ATM) proposals.
- *Economic Assessment:* the models are to be used to estimate the economic impacts associated with the whole life maintenance of the existing and proposed crossings, along with the construction impacts associated with the proposed new crossing. The benefits associated with the Active Traffic Management (ATM) proposals are also to be assessed using the local area models.
- *Environmental Assessment:* the local area S-Paramics models are also used to assess the emissions impacts associated with the proposed scheme and the ATM proposals in more detail than is possible using the strategic model

The review of the local area S-Paramics modelling was based on an examination of the different development phases of the Base, Do Minimum and Scheme models. The review also examined the Active Traffic Management (ATM) models. Furthermore, the review examined the approach and methodology adopted to assess the Whole Life Maintenance Impacts and Construction Impacts, the outputs of which are being used to supplement the overall strategic TMfS / TUBA based economic assessment.

The TTAA's review also included running a series of sensitivity tests based on a further development of the Jacobs-Arup Do Minimum and Scheme models. The TTAA's further developments included an alternative forecasting methodology as well as additional network updates. A comparison of the TTAA models against the equivalent Jacobs-Arup models was undertaken in terms of differences in traffic flows, congestion and journey times.

Conclusions

The TTAA is generally satisfied that the final versions of the local area models developed by Jacobs-Arup are reasonably robust and are reasonably fit for the purpose of undertaking some aspects of the local area modelling assessments e.g. the basic, relative emissions analysis comparing Do Minimum and Scheme. The Jacobs-Arup models do however show relatively low levels of queuing and congestion in future years and relatively low cross Forth journey times compared to the TTAA models. It is likely therefore that the Jacobs-Arup models will potentially underestimate any economic or operational impacts / benefits associated with the scheme as well as any potential emissions impacts / benefits associated with the introduction of ATM / ITS. A degree of care is therefore needed when interpreting outputs from these models.

It was however noted that the economic assessments carried out using the local area models only contributed around 10% to the overall economic benefits attributed to the proposed scheme. Furthermore, as these local benefits are additional benefits, any underestimate would tend to err on the side of caution.

The TTAA models, which are essentially a further development of the Jacobs-Arup models but include an alternative forecasting methodology as well as further network updates etc., show intuitively more realistic levels of future year congestion etc.. These models are therefore considered the most appropriate models for any further / updated operational or economic assessments. For consistency and robustness, it is recommended that the TTAA models should be used for any further local area analysis or assessments e.g. operational, economic or environmental assessments.

1 INTRODUCTION

1.1 Purpose of Report

This Forth Replacement Crossing (FRC) Local Area Modelling Audit Report presents the findings of the Traffic and Transport Advisor and Auditor's (TTAA's) review of the development of the local area models used to assess the local traffic, economic, operational and environmental impacts of the FRC.

The report is the culmination of various Audit Notes which the TTAA has issued, details of which are summarised below.

1.2 Background

In January 2008 SIAS, as part of the Traffic & Transport Advisor & Auditor commission (TTAA), was requested by Transport Scotland (TS) to undertake a review and audit of the transport modelling work associated with the Forth Replacement Crossing study. The modelling work had been carried out by the Jacobs-Arup Joint Venture. The review and audit were intended to cover all aspects of the modelling work including both the strategic modelling and the local area modelling.

The strategic modelling was based on the application of the Transport Model for Scotland (TMfS) and was used to assess the wide area traffic and economic impacts of the proposed scheme. Outputs from TMfS were input to the Department for Transport's Transport User Benefits Appraisal (TUBA) economic assessment software to undertake the core strategic economic assessment. The strategic modelling outputs were also used to inform the air quality assessment within the DMRB Stage 3 Environmental Statement.

The local area modelling was based on the development and application of an S-Paramics microsimulation model. The study area covered by the local area S-Paramics model was primarily confined to the Forth Crossing corridor. Note: "S-Paramics" and "Paramics" should be considered interchangeable in the context of this document and all relate to the use of the S-Paramics software.

Objectives of Local Area Modelling

The primary objectives of the local area S-Paramics models can be summarised as follows:

- *Operational Assessment:* the models are to be used to assess the more detailed operational aspects of the proposed scheme including the Active Traffic Management (ATM) proposals.
- *Economic Assessment:* the models are to be used to estimate the economic impacts associated with the whole life maintenance of the existing and proposed crossings, along with the construction impacts associated with the proposed new crossing. The economic benefits associated with the Active Traffic Management (ATM) proposals are also to be assessed using the local area models.
- *Environmental Assessment:* the local area S-Paramics models are also to be used to assess the emissions impacts associated with the proposed scheme and the ATM proposals in more detail than would be possible using the strategic model.

The outputs from the local area model assessments are to be used to supplement the wide area strategic environmental impacts and core economic impacts which have been determined using the strategic TMfS model.

Supplementary results from initial local area economic and environmental assessments were included within the DMRB Stage 3 Scheme Assessment Report Part 2: Engineering, Traffic and Economic Assessment (published November 2009). It should be noted that the local area economic and emissions assessments included within the DMRB Stage 3 Scheme Assessment Report were based on early versions of the Local Area Do Minimum and Scheme models which had not been audited or approved by the TTAA. However, as the results from these early models were only used to supplement the wider area strategic / core economic and environmental assessments, the use of the unaudited models was not considered a risk within the overall DMRB Stage 3 assessment. Discussed further in Chapter 8.

In addition to developing local area models to assess the operational, economic and environmental impacts of the overall scheme proposals, Jacobs-Arup also developed mini-junction models to assess the operational performance of the proposed specimen designs for the Ferrytoll and Queensferry junctions which connect the FRC to the existing road network. TS advised that the junction layouts etc. tested using these mini-junction models were subject to scrutiny and review by the MTRIPS Standards Branch to ensure they met the necessary DMRB requirements. As a result, Transport Scotland considered that no formal review of the mini-junction models was necessary and none is presented in this Local Area Modelling Report.

Although there are direct inputs to the local area modelling from the strategic modelling, the audit / review of the strategic modelling and the local area modelling have essentially been carried out separately. As a result, two Audit Reports have been prepared, namely:

- *Forth Replacement Crossing Strategic Modelling Audit Report*
- *Forth Replacement Crossing Local Area S-Paramics Modelling Audit Report*

This report represents the Forth Replacement Crossing Local Area S-Paramics Modelling Audit Report.

2 AUDIT / REVIEW

2.1 Introduction / Background

The local area S-Paramics modelling audit was based on a review of documentation received from Jacobs-Arup, along with a review of various model inputs and outputs also received. Throughout the audit / review process, the timescales available varied for differing aspects of the audit and in some cases were extremely tight. As a result, the TTAA was not always able to spend the time considered necessary to carry out a fully detailed audit and therefore some areas of the audit were based on a high level review as opposed to a detailed audit. The TTAA is however satisfied that the high level review was sufficiently detailed to determine the overall robustness of the local area modelling assessment.

2.2 Audit Issues, Recommendations & Confirmations

Various Audit Notes were prepared by the TTAA during the assessment and review of the different phases of the local area modelling. The Audit Notes presented Audit Issues, audit Recommendations and audit Confirmations as detailed below:

- *Audit Issues*: areas of the assessment / appraisal which the TTAA has identified where additional information / clarification is needed or where a different approach is considered necessary.
- *Recommendations:* areas of the assessment / appraisal where the TTAA would recommend additional information / clarification is needed or where a different approach is considered necessary.
- *Confirmations:* areas of the assessment / appraisal which the TTAA is generally content with and therefore generally content to sign off.

As the audit / review progressed, Jacobs-Arup requested that the TTAA clarify / identify the seriousness of the Audit Issues and Recommendations being made. It was therefore agreed with Jacobs-Arup to prioritise the Audit Issues and Recommendations with the following weightings / markers:

- *Major*
  The TTAA considers the Audit Issue or Recommendation needs to be addressed or discussed fully with the TTAA before the model, etc. is used (and/or any results based on the model presented) before the audit/review can be completed.
- *Medium*
  The TTAA considers an update or amendment may be required or may be beneficial, or that sensitivity testing would be useful. The TTAA does not however consider the issue serious enough to stop the model etc. being used.
- *Minor*
  The TTAA would seek clarification regarding a key point or additional information etc., but does not consider the issue serious enough to stop the model, etc. being used.

The above weightings / markers were only applied to the Audit Issues and Recommendations identified in the later Audit / Review Notes (Audit Note AN8 onwards).

2.3 Audit Notes Issued as Part of Local Area S-Paramics Modelling Review

The following formal Audit Notes, associated with the review of the FRC local area modelling, were issued by the TTAA:

- *Modelling Audit Note AN1 (20 October 2008, Ref. 70422)*
- *Audit Note AN5: Stage 3 S-Paramics Model Network Review (5 Dec 08, Ref.. 70614)*
- *Audit Note AN6: 2008 Base Model Development & validation (23 Dec 08, Ref. 70679)*
- *Audit Note AN7: Stage 3 S-Paramics Model Development & Calibration Review (26 May 09, Ref. 71386)*
- *Audit Note AN8: Stage 3 S-Paramics Model Matrix Development Methodology Review (3 June 09, Ref. 71434)*
- *Audit Note AN10: Review of Jacobs-Arup's Responses to Audit Note AN7 & FRC Stage 3 Paramics Model Development Report (29 June 09, Ref. 71530)*
- *Audit Note AN12: Review of Jacobs-Arup's Stage 3 Modelling – Future Year Traffic Forecast Development Methodology (24 Sept 09, Ref. 71869)*
- *Audit Note AN15: Stage 3 S-Paramics Base Model Final Review (4 Dec 09, Ref. 72204)*
- *Audit Note AN16: Review of Jacobs-Arup's Responses to AN12 and Stage 3 Paramics Modelling – Future Year Traffic Forecast Methodology (11 Dec 09, Ref. 72213)*
- *Audit Note AN17: Review of Jacobs-Arup's Updated Stage 3 Paramics Modelling – Future Year Demand Methodology – Alternative Application of TMfS Absolute Difference Growth Forecasts (21 April 10, Ref. 72684)*

Note: the Audit Notes etc. are not necessarily numbered consecutively given the reviews of the strategic modelling and the local area modelling were carried out in parallel.

As the audit of the local area Paramics models progressed, and as different phases of the local area models were developed, the Audit Issues and Recommendations presented in the earlier Audit Notes were generally addressed and / or taken on board.

2.4 Review of Audit Issues, Recommendations & Confirmations

A summary review of the Audit Issues and Recommendations associated with the local area S-Paramics models made by the TTAA in the above Audit Notes is presented in Chapters 3 to 12 below, along with discussions of various responses etc. received from Jacobs-Arup. The summary also indicates whether the TTAA was satisfied with the responses received and therefore whether the Audit Issue or Recommendation can be considered to have been satisfactorily addressed etc. Also presented are various Confirmations associated with the local area modelling which the TTAA presented in the Audit Notes etc.

The above Audit Notes examine the different phases of the development of the local area models, namely: Base; updated Base; Do Minimum; and Scheme models, as well as the forecasting methodology adopted to generate the 2017 future year matrices.

2.5 Local Area S-Paramics Models – Different Phases of Base Model Development

The development of the local area Paramics models involved a number of phases as summarised below. It should be noted that the term "phase" in this Audit Note refers to the different phases of Base Model development as outlined below. The term "stage" relates to the differing Stages of Road Scheme Assessment as outlined in DMRB Vol. 5, Section 1, Part 4, SH 1/97. The two terms should therefore not be considered interchangeable in the context of this Audit Note.

Phase 1 Models

The original Local Area S-Paramics Models developed by Jacobs-Arup were based on models which had been primarily developed for the Forth Estuary Transport Authority (FETA) to assess various maintenance scenarios associated with the Forth Road Bridge. The FETA models were developed for a 2006 Base year and were updated by Jacobs-Arup during the spring / summer of 2008. The original local area models developed by Jacobs-Arup from the FETA models were known as Phase 1 models.

Phase 2 Models

Whilst the 2006 FETA Base year models could be seen as a reasonable starting point for the development of models suitable for assessing the Forth Replacement Crossing, it was recognised that there were a number of limitations which needed to be overcome, including:

- *The FETA models assumed tolls were in place on the Forth Road Bridge*
- *The FETA models did not include the M9 spur*
- *The FETA models covered a relatively large area north and south of the Forth*

To overcome these issues the FETA models were largely re-developed by Jacobs-Arup to more closely suit the objectives of the FRC study – the re-developed models were known as Phase 2 models. The Phase 2 Base models were developed by Jacobs-Arup between June 2008 and April 2009 and were reviewed / audited throughout by the TTAA.

Phase 3 Models

In July 2009 the TTAA was requested to assist Jacobs-Arup in updating their Phase 2 Base models to overcome / address various Audit Issues and Recommendations identified by the TTAA. The updated Base models, which included the TTAA's revisions etc., were known as Phase 3 models. The Phase 3 Base models were released in September 2009.

In updating the Phase 2 Base models the TTAA essentially worked through the various Audit Issues and Recommendations previously identified and took these on board. As a result, the majority of the Audit Issues & Recommendations presented in the early Audit Notes associated with the Phase 1 and Phase 2 Base models are either no longer applicable, or were eventually taken on board / addressed during the development of updated models - discussed in more detail below.

Phase 4 Models

The Phase 3 Base models developed by the TTAA were independently checked and audited by GK-TC (a consultancy firm specialising in Paramics modelling). The Phase 3 models were then passed back to Jacobs-Arup for further updates and refinements which were considered necessary – the updated models then became known as Phase 4 Base models.

Up to this point only AM and PM models had been developed at each Phase. However, Jacobs-Arup developed an Inter-Peak Base model based on the Phase 4 AM and PM Base models - the updated models, including the Inter-Peak period representation, were known as the Phase 5 models.

Phase 5 Models

The Phase 5 Base models, which included the Inter-Peak period, became the building block / starting point on which to develop the Do Minimum and Scheme models. During the development of the future year Do Minimum and Scheme models various forecasting methodologies were proposed to develop the forecast matrices. The Phase 5 Base models were finalised in November 2009.

A summary of the different Base models and future year model development etc. is presented in Table 2.1. Table 2.1 also summarises where the models have been applied to date.

Summary Table of Base Model & Do Min & Scheme Model Development etc.

Base Year Model Development

Phase	Development Period	Date Released	Discussed in Audit Note
1	Feb 08 to Aug 08	Autumn 2008	AN1, AN6
2	Aug 08 to Apr 09	Spring 2009	ANs 5, 7, 8 10
3	Jul 09 to Sept 09	Sept 2009	Briefing Note Nov09
4	Nov-09	Nov 2009	AN15
5	Nov-09	Nov 2009	AN15

Future Year Model Development

Future Year Forecast Models	Base Phase	Forecast Model Work Period	Developed by Jacobs / TTAA?	Forecast Methodology	Discussed in Audit Note
A	2	Apr 09 to Sept 09	Jacobs	Furnessed	AN8, AN13
B	5	Sept 09 to May 10	Jacobs	Incremental Jacobs	AN12, AN1, AN17
C	5	May 10 to Aug 10	Jacobs + TTAA	Incremental TTAA	TTAA Note - Appendix A

Model Application to Date (@ Oct 10)

Future Year Forecast Models	Operational[1]	Economic[2]	Environmantal (PHEM)[3]	Results Reported in?
A	√	√	√	DMRB Stage 3 Nov 09
B			√	
C			√	

Notes:

[1] Scheme layout / junction arrangements / ITS operation etc.

[2] Supplementary local area economic benefits etc. associated with Whole Life Maintenance Impacts; Construction Impacts; ITS

[3] Supplementary local area Carbon emissions determined using PHEM - Passenger Car & Heavy Duty Emissions Model

Table 2.1: Summary Table of Base Model & Future Year Model Development

The TTAA's review of the Phase 1 to Phase 5 Base models is presented in Chapters 3 to 5.

2.6 Assessments Undertaken Using Early Versions of the Local Area Models

During the time the Base models were being updated, Jacobs-Arup continued with their on-going assessment of the maintenance and construction impacts associated with the existing and proposed crossings. They also undertook an assessment of the proposed ATM measures. These assessments included an examination of the local economic and environmental impacts. The results of these assessments were used to supplement the strategic / core economic and environmental assessments obtained from the strategic TMfS models.

The supplementary local assessments were carried out using early versions of local area Paramics models (Future Year Forecast Models A in Table 2.1) which would eventually be replaced by more robust models developed from suitably calibrated and validated Base models (Future Year Forecast Models B & C in Table 2.1). It was however accepted that the early models would provide a reasonable indication of the maintenance and construction impacts, as well as the ATM impacts, and that updated assessments could be undertaken if considered necessary once the updated models were available e.g. if large differences between the models were found.

The TTAA however agreed to review the methodology etc. being applied to the assessment of the maintenance and construction impacts. The TTAA's review is included in:

- *Audit Note AN13: Review of Jacobs-Arup's Do Minimum Maintenance & Construction Impacts Economic Evaluation (30 Sept 09, Ref. 71870)*

A discussion of Audit Note AN13 is presented in Chapter 8.

3 PHASE 1 BASE YEAR MODELLING

3.1 Introduction / Background

As outlined above, the original Local Area S-Paramics Models developed by Jacobs-Arup were initially based on models which had been primarily developed for the Forth Estuary Transport Authority (FETA) to assess various maintenance scenarios associated with the Forth Road Bridge. The FETA models were developed for a 2006 Base year and were updated by Jacobs-Arup during the spring / summer of 2008. The original local area models developed by Jacobs-Arup from the FETA models were known as Phase 1 models.

The TTAA's review of the Phase 1 Base models was presented in Audit Notes AN1 & AN6

3.2 Review of Audit Note AN1

Audit Note AN1 contained a review of the following documentation associated with the early S-Paramics models, received from Jacobs-Arup:

- *FRC Paramics Model Audit Technical note, April 2008*
- *FRC Paramics Model Scoping Report, July 2008*

Audit Note AN1 highlighted a number of Audit Issues associated with applying the FETA models to the Forth Replacement Crossing study and presented a number of Recommendations which the TTAA considered needed to be taken on board if the FETA models were to be applied. Whilst the TTAA considered the 2006 FETA Base year models could be seen as a reasonable starting point for the development of models suitable for assessing the Forth Replacement Crossing, the TTAA highlighted a number of limitations which needed to be overcome if the models were to be applied. These included:

- *The FETA models assumed tolls were in place on the Forth Road Bridge*
- *The FETA models did not include the M9 spur*
- *The FETA models covered a relatively large area north and south of the Forth*

Given these limitations the principal Recommendation presented in Audit Note AN1 was:

> **Recommendation AN1 R1:** *The TTAA would recommend that given objectives of the FRC study differ considerably to the objectives of the FETA study, the FETA models should simply be seen as a starting point for the development of local area FRC Paramics models. Any updates to the FETA models will require a degree of re-calibration and re-validation.*

3.3 Review of Audit Note AN6

Audit Note AN6, presented the findings of the TTAA's review and audit of the Jacobs-Arup Phase 1 Base model development and validation. This was based on a review of the information etc. presented in the following document (received on 27 November 2008):

- *Forth Replacement Crossing Traffic & Economic Stage 2 Assessment: 2008 Paramics Base Model Development & (Re) Validation Report, November 2008 (Draft)*

Audit Note AN6 highlighted a number of areas where in the TTAA's opinion the Phase 1 Base models could be revised and enhanced in order to improve the calibration and validation of the models.

As a result, the principal Recommendation presented in Audit Note AN6 associated with the calibration and validation of the Phase 1 Base models was:

> ***Recommendation AN6 R9:*** *The TTAA would recommend that further updates and calibration are required before the models can be considered to be sufficiently robust for the Stage 2 assessments.*

3.4 Addressing the Audit Issues & Recommendations Presented in Audit Notes AN1 & AN6 - Development of Phase 2 Base Models

Following various meetings and discussions with the TTAA, Jacobs-Arup agreed that in order to overcome the issues associated with the FETA models outlined above, and in order to improve the calibration and validation of the local area models, updated models needed to be developed. Jacobs-Arup therefore elected to largely re-develop the FETA models such that their revised / updated models more closely suited the objectives of the FRC study. The re-developed models were known as Phase 2 models and were developed by Jacobs-Arup between June 2008 and April 2009.

Given the decision by Jacobs-Arup to develop Phase 2 Base models the TTAA is generally satisfied that the Audit Issues and Recommendations associated with the early local area modelling presented in Audit Notes AN1 and AN6 are largely no longer applicable. Furthermore, the TTAA is satisfied that the principal Recommendations AN1 R1 and AN6 R9 have been satisfactorily addressed.

Confirmation LMAR C1: The TTAA is generally satisfied that Audit Issues associated with the local area modelling presented in Audit Note AN1 are either no longer applicable and / or have been satisfactorily addressed during the development of the final Base models (released November 2009).

Confirmation LMAR C2: The TTAA is TTAA is satisfied that the Recommendations associated with the local area modelling presented in Audit Note AN1 are either no longer applicable and / or have been satisfactorily addressed during the development of the final Base models (released November 2009).

Confirmation LMAR C3: The TTAA is generally satisfied that Audit Issues associated with the local area modelling presented in Audit Note AN6 are either no longer applicable and / or have been satisfactorily addressed during the development of the final Base models (released November 2009).

Confirmation LMAR C4: The TTAA is TTAA is satisfied that the Recommendations associated with the local area modelling presented in Audit Note AN6 are either no longer applicable and / or have been satisfactorily addressed during the development of the final Base models (released November 2009).

4 PHASE 2 BASE YEAR MODELLING

4.1 Introduction/Background

In the summer of 2008, Jacobs-Arup decided to largely re-develop the Phase 1 FETA models to ensure that their local area Paramics models more closely reflected the objectives of the FRC study. The re-developed models were known as Phase 2 models.

The Phase 2 Base models were largely developed by Jacobs-Arup between August 2008 and April 2009. During this period the TTAA undertook a series of reviews of different elements of the Phase 2 models' development. A number of Audit Notes were produced which dealt with the development of the Phase 2 Base models, including:

- *Audit Note AN5: Stage 3 S-Paramics Model Network Review (5 Dec 08, Ref. 70614)*
- *Audit Note AN7: Stage 3 S-Paramics Model Development & Calibration Review (26 May 09, Ref. 71386)*
- *Audit Note AN8: Stage 3 S-Paramics Model Matrix Development Methodology Review (3 June 09, Ref. 71434)*
- *Audit Note AN10: Review of Jacobs-Arup's Responses to Audit Note AN7 & FRC Stage 3 Paramics Model Development Report (29 June 09, Ref. 71530)*

Audit Notes AN5, AN7, AN8 and AN10 are discussed further below.

4.2 Audit Note AN5: Stage 3 S-Paramics Model Network Review (5 Dec 08, Ref. 70614)

Audit Note AN5 was issued by the TTAA in December 2008 and contained a review of the following S-Paramics information received from Jacobs-Arup:

- *S-Paramics 2008 Base Network Only (i.e. no finalised demand data).*
- *Digital background from which the model has been constructed (dxf).*
- *Jacobs-Arup Stage 3 Technical Note 1: Forth Replacement Crossing – Stage 3 Technical Note 1 – Model Setup and Configuration.*

The review presented in Audit Note AN5 concentrated on the network construction, model coding, and the configuration parameters used within the model. The review did not cover the collection / collation of observed data, demand data developments, or the model calibration / validation etc. (Covered in Audit Note AN7)

Audit Note AN5 presented several Audit Issues associated with the early development of the Phase 2 Base models and made a number of Recommendations.

However, the Phase 2 Base models were eventually updated with final (Phase 5) versions released in November 2009. The final Base models addressed / took on board all the Audit Issues presented in Audit Note AN5. The TTAA is therefore generally satisfied that all the Audit Issues presented in Audit Note AN5 associated with the development of the early Base models were satisfactorily addressed during the development of the final (November 2009) Base models.

Confirmation LMAR C5: The TTAA is generally satisfied that all the Audit Issues presented in Audit Note AN5 associated with the development of early Base models were satisfactorily addressed during the development of the final Base models (released November 2009).

Similarly, as outlined above, the Recommendations presented in Audit Note AN5 were associated with Phase 2 versions of the Base models. These Phase 2 Base models were eventually updated with final versions released in November 2009. The final Base models addressed / took on board all the Recommendations presented in Audit Note AN5. The TTAA is therefore generally satisfied that all the Recommendations presented in Audit Note AN5 associated with the development of the Phase 2 Base models were satisfactorily addressed during the development of the Phase 3 to 5 Base models.

Confirmation LMAR C6: The TTAA is generally satisfied that all the Recommendations presented in Audit Note AN5 associated with the development of early Base models were satisfactorily addressed during the development of the final Base models (released November 2009).

4.3 Audit Note AN7: Stage 3 S-Paramics Model Development & Calibration Review (26 May 2009, Ref. 71386)

Audit Note AN7, presented the findings of the TTAA's review and audit of the Jacobs-Arup Phase 2 Base model development and calibration and was based on a review of the following information etc. passed to the TTAA:

- *S-Paramics 2008 Base Model including what Jacobs-Arup refer to as 'proposed' demand matrices and demand profiles.*
- *Link and turn flow comparison figures in the vicinity of each of the motorway junctions for each hour modelled across the AM 06:00 – 10:00 and PM 15:00 – 19:00 periods.*

The TTAA's review of this information, together with the review of the latest versions of the Phase 2 Base models, identified a number of Audit Issues as presented in Audit Note AN7. In addition, a number of Recommendations were also presented in Audit Note 7. The underlying theme to the majority of the Audit Issues and Recommendations presented in Audit Note AN7 was that further work was necessary in developing the Phase 2 models. The principal Recommendation in AN7 was:

> ***Recommendation AN7 R15:*** *The TTAA would recommend that further improvements to the model flow comparisons are required e.g. changes to the model, the demand matrices and / or demand profiles. (A review of the demand matrices will be presented in Audit Note AN8).*

As outlined above, the Phase 2 Base models reviewed in Audit Note AN7 were later updated. As a result, the Audit Issues and Recommendations presented in Audit Note AN7 are either no longer considered applicable or have been addressed during the development of the final updated models (Phase 5) – discussed further below.

Confirmation LMAR C7: The TTAA is generally satisfied that all the Audit Issues associated with the Phase 2 local area modelling presented in Audit Note AN7 are largely no longer applicable and / or have been satisfactorily addressed during the development of the final Base models (released November 2009).

Confirmation LMAR C8: The TTAA is generally satisfied that all the Recommendations associated with the Phase 2 local area modelling presented in Audit Note AN7 are largely no longer applicable and / or have been satisfactorily addressed during the development of the final Base models (released November 2009).

4.4 Audit Note AN8: Stage 3 S-Paramics Model Matrix Development Methodology Review (3 June 09, Ref. 71434)

Audit Note AN8, presented the findings of the TTAA's review and audit of the Jacobs-Arup DMRB Stage 3 S-Paramics Forth Replacement Crossing (FRC) microsimulation matrix development methodology and the corresponding trip matrices. The models reviewed within Audit Note AN8 were the Phase 2 Base models which had been developed and updated by Jacobs-Arup.

The review presented in Audit Note AN8 was based on an examination of the following documentation and models passed to the TTAA:

- *Jacobs-Arup report, Stage 3 Paramics Modelling – Base Model Matrix Estimation (ME) Methodology (Technical Note TN-ST3-P01 – Draft Version 3)*
- *AM and PM TMfS cordon matrices, prior furnessed matrices, and what Jacobs-Arup refer to as 'proposed' S-Paramics demand matrices*
- *S-Paramics 2008 Base Model including 'proposed' demand matrices and demand profiles.*
- *Link and turn flow comparison figures in the vicinity of each of the motorway junctions for each hour modelled across the AM 06:00 – 10:00 and PM 15:00 – 19:00 periods.*
- *Details of alterations made to the 'proposed' S-Paramics demand matrices based on the inclusion of additional zones.*

The TTAA's review of the above documentation and models identified a number of Audit Issues. In addition, the TTAA made a number of Recommendations where the matrix methodology etc. proposed could be improved. The principal Recommendation presented in Audit Note AN8 was:

> ***Recommendation AN8 R9:*** *The TTAA would recommend a review of the matrix development process is undertaken as this is expected to lead to improved flow calibration results and overall model calibration and validation. (Major)*

The Base models and matrix methodology reviewed in Audit Note AN8 were however later updated. As a result, the Audit Issues and Recommendations presented in Audit Note AN7 are either no longer considered applicable or have been addressed during the development of the final updated models (Phases 3 to 5) – discussed further below.

Confirmation LMAR C9: The TTAA is generally satisfied that the Audit Issues associated with the Phase 2 Base models and presented in Audit Note AN8 are largely no longer applicable and / or have been satisfactorily addressed during the development of the final Base models (released November 2009).

Confirmation LMAR C10: The TTAA is generally satisfied that the Recommendations associated with the Phase 2 Base models presented in Audit Note AN8 are largely no longer applicable and / or have been satisfactorily addressed during the development of the final Base models (released November 2009).

4.5 Audit Note AN10: Review of Jacobs-Arup's Responses to Audit Note AN7 & FRC Stage 3 Paramics Model Development Report (29 June 09, Ref. 71530)

Audit Note AN10 presented a review of Jacobs-Arup's response to Audit Note AN7. It also included a review of the Jacobs-Arup FRC Stage 3 Paramics Model Development Report. The Development Report contained additional information and responses relating to a number of the Audit Issues and Recommendations raised by the TTAA in AN7, along with further details of the Phase 2 Base model calibration and validation.

The review presented in Audit Note AN10 was based on an examination of the following information:

- *Jacobs-Arup Audit Response Note ARN-ST3-P02 – Draft Response to Audit Note AN7 Stage 3 Paramics Model Development & Calibration Review (29 May 2009)*
- *Jacobs-Arup FRC Stage 3 Traffic & Economic Assessment Paramics Model Development Report (11 June 2009 – Draft)*
- *Jacobs-Arup Stage 3 Paramics Modelling – Base Model Matrix Estimation Methodology (Technical Note TN-ST3-P01 – Draft Version 3, 15 May 2009)*
- *TTAA's Audit Note AN7 - Stage 3 S-Paramics Model Development & Calibration Review (26 May 2009, Ref. 71386)*

Based on the TTAA's review of the information and models etc. outlined above, Audit Note AN10 presented a summary of the (then) situation regarding the various Audit Issues etc. previously presented in Audit Note AN7, taking into account the responses and additional information received to date from Jacobs-Arup. Whilst Audit Note AN10 confirmed that a number of the earlier Audit Issues had been satisfactorily addressed, it also highlighted that a large number remained outstanding.

Therefore whilst the TTAA was able to confirm that a number of areas of the Phase 2 modelling were considered satisfactory, the TTAA remained concerned that the final Phase 2 models did not sufficiently meet the necessary calibration and validation acceptability criteria as presented in the Design Manual for Roads & Bridges (DMRB), particularly in key locations relevant to the FRC Scheme Assessment. As a result, the principal Recommendation associated with the Phase 2 Base models presented in Audit Note AN10 was:

> **Recommendation AN10 R1:** *The TTAA would recommend that the Phase 2 Base models need to be updated such that their calibration and validation meet the DMRB criteria. (Major)*

4.6 Addressing the Audit Issues & Recommendations Presented in Audit Note AN10 - Development of Phase 3 Base Models

Given the TTAA's ongoing concerns with the Phase 2 Base models and their generally unsatisfactory levels of calibration and validation, particularly in key locations relevant to the FRC Scheme Assessment, in July 2009 Transport Scotland asked the TTAA to assist Jacobs-Arup in updating the models etc. such that the various Audit Issues and Recommendations identified were fully addressed. This resulted in the development of Phase 3 Base models which were released in September 2009.

In updating the Phase 2 Base models the TTAA essentially worked through the various Audit Issues and Recommendations identified in Audit Notes 5, 7, 8 and 10 and took these on board. As a result, the TTAA is generally satisfied that the Audit Issues & Recommendations presented in these Audit Notes have been addressed / taken on board.

Furthermore, given the development of the Phase 3 Base models, the TTAA is generally satisfied that the Audit Issues and Recommendations relating to the Phase 2 Base Model Development presented in Audit Note 10 have either been satisfactorily addressed or are no longer applicable.

Confirmation LMAR C11: The TTAA is generally satisfied that the Audit Issues associated with the Phase 2 Base models presented in Audit Note AN10 are largely no longer applicable and / or have been satisfactorily addressed.

Confirmation LMAR C12: The TTAA is generally satisfied that the Recommendations associated with the Phase 2 Base models presented in Audit Note AN10 are largely no longer applicable and / or have been satisfactorily addressed.

5 PHASE 3 TO 5 BASE YEAR MODELLING

5.1 Introduction/Background

As outlined above, in July 2009 Transport Scotland asked the TTAA to assist Jacobs-Arup in updating their Phase 2 models etc. to ensure that the various Audit Issues and Recommendations identified were fully addressed. To achieve this, the TTAA redeveloped the Base models by working through and taking on board the various Audit Issues and Recommendations presented in Audit Notes 5, 7, 8 and 10. This resulted in the development of the Phase 3 Base models which were released in September 2009.

The Phase 3 Base models developed by the TTAA were independently checked and audited by GK-TC (a consultancy firm specialising in Paramics modelling). The Phase 3 models were then passed back to Jacobs-Arup for further updates and refinements which were considered beneficial – the updated models then became known as the Phase 4 Base models.

Up to this point, given the original objective of the local area models had been for operational and ITS analysis, only AM and PM models had been developed at each Phase. However, as the local area models were now intended to be used to assess the local economic and environmental impacts, it was considered necessary to develop an Inter-Peak model. Jacobs-Arup therefore developed an Inter-Peak Base model from the Phase 4 AM and PM Base models. The updated models, including the Inter-Peak period representation, became known as the Phase 5 Base models and were finalised in November 2009.

The final Phase 5 Base models were passed back to the TTAA to review in November 2009. The outcome of the TTAA's review was presented in Audit Note AN15. The Phase 5 Base models then became the starting point for developing the Do Minimum and Scheme models.

5.2 Audit Note AN15: Stage 3 S-Paramics Base Model Final Review (4 Dec 09, Ref. 72204)

The review presented in Audit Note AN15 was based on an examination of the following information:

- Phase 3: Jacobs–Arup Memo, *Forth Replacement Crossing – Review of SIAS Recalibrated Base Paramics Model (1 October 2009)*
- Phase 3: SIAS Briefing Note, *Stage 3 S-Paramics Model Update/Re-Calibration (SIAS Ref. 72046, 4 November 2009)*
- Phase 4: Jacobs–Arup Technical Note *TN-ST3-P12, Stage 3 Paramics Modelling – Further Improvements to SIAS Recalibrated Base Model (16 November 2009)*
- Phase 5: Jacobs–Arup Technical Note *TN-ST3-P13, Stage 3 Paramics Modelling – Inter Peak Demand Matrix Development Methodology (19 November 2009)*

Based on a review of the documents and the associated updated Base models outlined above, the TTAA presented a small number of further but relatively minor Audit Issues and Recommendations in Audit Note AN15.

Audit Note AN15 concluded that the revised (Phase 4) AM and PM Base models sufficiently met the *DMRB* acceptability guidelines. The models were therefore considered suitable for the intended FRC assessment on the strategic road network within the local study area and as a suitable starting point for the development of Do Minimum and Scheme future year models.

With regard to the Inter-Peak models, Audit Note AN15 identified a number of improvements which could be made e.g. the public transport elements. In addition, a relatively small number of Audit Issues were identified associated with the Inter-Peak matrix development. Whilst the Inter-Peak Base models showed a reasonable level of calibration had been achieved, the data available for these comparisons was considerably more limited than for the AM and PM periods. The IP period could therefore only be considered to represent a coarse synthesis of the traffic patterns and volumes within this period and this should to be borne in mind when applying the Do Minimum and Scheme models and interpreting its outputs.

The TTAA would therefore advise that some degree of care needs to be taken when interpreting any impacts or benefits predicted using the models to ensure that the influence of the outputs from the IP period are considered appropriately in comparison with those relating to the relatively more reliable AM and PM peaks.

A number of Confirmations were however presented in Audit Note AN15 associated with the Phase 5 Base models including:

Confirmation AN15 C1: Following the Phase 3 Base model update and re-calibration process, the TTAA was generally satisfied that the AM and PM Base Models were suitable for application to the FRC assessment on the strategic road network within the study area. This could potentially involve undertaking an economic evaluation of the ITS measures during the AM and PM peak periods, i.e. while the ITS is active, estimating emission outputs to feed into the overall environmental assessment, and reporting the relative journey time differences between modelled scenarios along the main strategic routes. The model's fitness for purpose for other more general applications would need to be verified on a case by case basis.

Confirmation AN15 C2: The TTAA is generally satisfied that the network alterations and the current Base Model network is appropriate.

Confirmation AN15 C3: The TTAA is generally satisfied that the application of the tighter constraint level on additional strategic movements and constraint alterations on key OD movements is appropriate.

Confirmation AN15 C4: The TTAA is generally satisfied that the calibration and validation of the AM and PM periods is acceptable in relation to the DMRB calibration/validation acceptability guidelines.

Confirmation AN15 C5: The TTAA is generally satisfied that the model setup with the inclusion of an IP period is appropriate.

Confirmation AN15 C6: The TTAA is generally satisfied that the model network and operation is appropriate.

Confirmation AN15 C7: The TTAA is generally satisfied that the IP expansion factors applied to turning count data are appropriate.

Confirmation AN15 C8: In general the TTAA is satisfied that the IP model is calibrated and validated to a level suitable for its intended application in this case, i.e. to provide an estimate of the possible emission outputs through this period and to provide an improved interaction between traffic within the AM and PM periods. However, the TTAA notes that irrespective of the apparently high level of calibration achieved (due to the limited amount of observed data available)**, the IP period only represents a coarse synthesis of the traffic patterns and volumes within this period and the more general application should be considered limited by this fact. This should also be borne in mind when applying the model and interpreting its outputs. In particular, care should be taken when interpreting any impacts or benefits predicted using the model to ensure that the influence of the outputs from the IP period can be considered in comparison with those relating to the relatively more reliable AM and PM peaks.**

Given the Confirmations presented in Audit Note AN15, the TTAA is generally satisfied that the Phase 5 Base models sufficiently meet the *DMRB* acceptability guidelines. Furthermore, the TTAA is generally satisfied that Phase 5 Base models are suitable for the intended FRC assessment on the strategic road network within the local study area and are a suitable starting point for the development of Do Minimum and Scheme future year models.

Confirmation LMAR C13: The TTAA is generally satisfied that the Phase 5 Base models meet the DMRB acceptability guidelines.

Confirmation LMAR C14: The TTAA is generally satisfied that the Phase 5 Base models are suitable for application to the intended FRC assessment on the strategic road network within the local study area and as the starting point for the development of Do Minimum and Scheme future year models.

6 FUTURE YEAR DO MINIMUM & SCHEME MODELLING

6.1 Introduction/Background

Audit Note AN15 concluded that the Phase 5 Base models were suitable for application to the intended FRC assessment on the strategic road network within the local study area. Furthermore, Audit Note AN15 concluded that the Phase 5 models were considered a suitable starting point for the development of Do Minimum and Scheme future year models.

6.2 Future Year Forecasting

During the development and updating of the Base models, in parallel Jacobs-Arup had prepared a number of methodology notes outlining their proposals to develop their future year demand matrices. These methodology notes were subject to various discussions with the TTAA. The TTAA's formal review of the forecast matrix proposals were presented in the following Audit Notes:

- *Audit Note AN12: Review of Jacobs-Arup's Stage 3 Modelling – Future Year Traffic Forecast Development Methodology (24 Sept 09, Ref. 71869)*
- *Audit Note AN16: Review of Jacobs-Arup's Responses to AN12 and Stage 3 Paramics Modelling – Future Year Traffic Forecast Methodology (11 Dec 09, Ref. 72213)*
- *Audit Note AN17: Review of Jacobs-Arup's Updated Stage 3 Paramics Modelling – Future Year Demand Methodology – Alternative Application of TMfS Absolute Difference Growth Forecasts (21 April 10, Ref. 72684)*

Audit Notes AN12, AN16 and AN17 are discussed further below.

6.3 Audit Note AN12: Review of Jacobs-Arup's Stage 3 Modelling – Future Year Traffic Forecast Development Methodology (24 Sept 09, Ref. 71869)

In September 2009, whilst the development and recalibration / revalidation of the local area Base models (Phase 3) was ongoing, Jacobs-Arup submitted a technical note which presented their proposed traffic forecasting methodology to be used to derive 2017 demand matrices for future year Do Minimum and Scheme models. The TTAA undertook a review of this methodology and reported the results of the review in Audit Note AN12.

The review presented in Audit Note AN12 was based on an examination of the following documentation received from Jacobs-Arup:

- *Stage 3 Paramics Modelling – Future Year Traffic Forecast Development, Technical Note TN-ST3-P11 Version 3 (dated 27 August 2009), received 3 September 2009.*

Based on a review of Technical Note TN-ST3-P11, the TTAA highlighted a number of Audit Issues associated with the original forecasting methodology proposed by Jacobs-Arup. Of particular concern to the TTAA was the Jacobs-Arup proposal to apply Furnessed growth, as opposed to absolute growth, in determining the future year Paramics matrices. Whilst the TTAA recognised that the Furnessing approach would increase trip end totals to match predicted levels, the TTAA was concerned that it could potentially distort or misrepresent the trip distribution predicted by the strategic model. Given the desire to retain the forecast strategic trip distribution pattern, the TTAA considered that evidence needed to be presented to demonstrate that the application of the Furnessing approach was not unduly affecting the distribution of growth predicted by the strategic model.

The principal Audit Issue raised in Audit Note AN12 was therefore:

> ***Audit Issue AN12 AI2:*** *The TTAA has some concerns regarding the decision to apply Furnessed growth as opposed to absolute growth in determining the future year Paramics matrices given potential changes in trip distribution may not be adequately reflected. The TTAA would therefore wish to see evidence that the trip distribution changes predicted by TMfS05A have been reflected in the growth process used to determine the forecast Paramics matrices, as well as a comparison of the TMfS growth increment with the resulting Paramics growth increment. (Major)*

6.4 Addressing the Audit Issues & Recommendations Presented in Audit Note AN12

In order to avoid the potential problems associated with the Furnessing process, the TTAA recommended that an incremental growth process should be applied in its place.

Further discussions on the forecast growth methodology took place between the TTAA and Jacobs-Arup. As part of these discussions Jacobs-Arup provided some further evidence to support their original view that the Furnessing approach was appropriate (discussed further in Audit Note AN16). However, following various meetings and discussions Jacobs-Arup agreed to amend their proposed forecasting methodology and apply the incremental growth approach in place of the Furnessing process.

As a result of the Jacobs-Arup decision to apply the incremental growth approach in place of the Furnessing process, the TTAA is satisfied that Audit Issue AN12 AI2 has been satisfactorily addressed.

In addition to the Audit Issue AN12 AI2, a small number of Medium and Minor Audit Issues were also raised by the TTAA in Audit Note AN12. The TTAA is however generally satisfied that each of these has either been addressed in the updated forecasting methodology and / or are no longer applicable. Confirmations to this effect were presented in Audit Note AN16.

Confirmation LMAR C15: The TTAA is generally satisfied that all the Audit Issues identified in Audit Note AN12 have been satisfactorily addressed given the updated forecasting methodology approach adopted.

6.5 Audit Note AN16: Review of Jacobs-Arup's Responses to AN12 and Stage 3 Paramics Modelling – Future Year Traffic Forecast Methodology (11 December 2009, Ref. 72213)

Audit Note AN16 contained a review of the Jacobs-Arup responses to earlier Audit Issues etc. presented in Audit Note AN12, as well as a review of the updated forecast matrix development.

The review presented in Audit Note AN16 was based on an examination of the following information:

- *Stage 3 Paramics Modelling – Future Year Demand Methodology, Technical Note TN-ST3-P02 ((dated 20 February 2009), received 18 March 2009).*
- *Stage 3 Paramics Modelling – Future Year Traffic Forecast Development, Technical Note TN-ST3-P11 Version 3 ((dated 27 August 2009), received 3 September 2009).*
- *Stage 3 Transportation Modelling – Response to Audit Note AN12: Review of Jacobs-Arup's Forecasting Methodology, Audit Response Note ARN-ST3-P04 Version 2 ((dated 5 November 09), received 18 November 09)*
- *TMfS Cordon and S-Paramics AM and PM Base Year and 2017 Do Minimum (Do Min) and 2017 With Scheme (Do Some) demand matrices (received 25 November 2009)*

The review also took account of the outcomes of various discussions between Jacobs-Arup and the TTAA during November and December 2009.

Audit Note AN16 was able to confirm that a number of the Audit Issues presented in Audit Note AN12 had now been satisfactorily addressed.

However, as outlined above, the TTAA had raised concerns in Audit Note AN12 regarding the future year demand matrix forecast methodology proposed by Jacobs-Arup, in particular their original proposals to adopt Furnessed growth. In response to the TTAA's request for additional information / evidence to support the use of the Furnessed growth approach, Jacobs-Arup submitted Audit Response Note ARN-ST3-P04 in November 2009.

Jacobs-Arup's Audit Response Note ARN-ST3-P04 presented information, tables and figures relating to the TMfS growth forecasts and the growth calculated for application within the S-Paramics future year matrices. Having reviewed this information, the TTAA noted that whilst it provided some comfort that the general TMfS and S-Paramics growth trends were not significantly different, the key issue related to whether the Furnessing process had altered the underlying TMfS predicted growth distribution. In the TTAA's opinion it had. This was discussed with Jacobs-Arup at a meeting held on 23 November 2009 and subsequent to this meeting Jacobs-Arup provided the TMfS cordon and S-Paramics AM and PM Base Year and 2017 Do Min and 2017 Scheme demand matrices.

The TTAA undertook a number of comparisons between the forecast TMfS cordon matrices and the forecast S-Paramics matrices and presented the results of these comparisons in Audit Note AN16. The TTAA considered the comparisons demonstrated that the forecasting process adopted by Jacobs-Arup to calculate the S-Paramics future year matrices had altered the forecast distribution predicted by TMfS. The TTAA considered this was likely to be an outcome of the Furnessing process which appeared to have changed the predicted growth distribution based on the distribution of trips within the S-Paramics base year matrices. In particular, the Base year matrices contained a higher number of internal trips (e.g. within the Dunfermline area) and it appeared that growth predicted by TMfS on strategic and external (e.g. cross-Forth) trips has been moved to internal trips.

Given the comparisons etc. presented by the TTAA in Audit Note AN16, the primary Audit Issue and Recommendation made in Audit Note AN16 focussed on the forecasting methodology, namely:

> ***Audit Issue AN16 AI3:*** *The TTAA considers that the forecasting approach adopted by Jacobs-Arup to calculate the S-Paramics future year matrices has significantly altered the forecast distribution predicted by TMfS. (Major)*
>
> ***Recommendation AN16 R1:*** *The TTAA would recommend applying the incremental growth to the future year matrices in order to maintain the TMfS growth distribution. Larger negative OD values, together with any relevant cells with large positive growth, should be investigated and appropriate measures taken to address these. The TTAA would wish to review any alterations made to the TMfS absolute growth increment when applying this within the S-Paramics model future year matrices. (Major)*

6.6 Addressing the Audit Issues & Recommendations Presented in Audit Note AN16

After various discussions with Jacobs-Arup, agreement was reached that the incremental approach should be applied in place of the Furnessing growth method. Any larger negative OD values resulting from the application of incremental growth would be investigated and resolved in a logical manner e.g. by distributing the negative growth onto adjacent corresponding OD movements. Sense and logic checks would also be undertaken on any large growth cells to ensure the growth was being applied in a robust and appropriate manner.

As a result of the Jacobs-Arup decision to apply the incremental growth approach in place of the Furnessing process, the TTAA is satisfied that Audit Issue AN16 AI3 and Recommendation AN16 R1 have been satisfactorily addressed.

In addition to Audit Issue AN16 AI3 and Recommendation AN16 R1, Audit Note AN16 presented a small number of Medium and Minor Audit Issues. The TTAA is however generally satisfied that each of these has either been addressed in the updated forecasting methodology and / or is no longer applicable.

Confirmation LMAR C16: The TTAA is generally satisfied that all the Audit Issues identified in Audit Note AN16 have been satisfactorily addressed given the updated forecasting methodology approach adopted.

Confirmation LMAR C17: The TTAA is generally satisfied that all the Recommendations identified in Audit Note AN16 have been satisfactorily addressed given the updated forecasting methodology approach adopted.

6.7 Audit Note AN17: Review of Jacobs-Arup's Updated Stage 3 Paramics Modelling – Future Year Demand Methodology – Alternative Application of TMfS Absolute Difference Growth Forecasts (21 April 2010, Ref. 72684)

As outlined above, the TTAA had recommended that Jacobs-Arup needed to reconsider their proposed forecast matrix methodology and revise their proposals to apply a Furnessing process which the TTAA had demonstrated was altering the trip distributions forecast by TMfS. Audit Note AN17 therefore presented a review of the Jacobs-Arup Updated Stage 3 Paramics Modelling – Future Year Demand Methodology – Alternative Application of TMfS Absolute Difference Growth Forecasts.

The principal recommendation presented by the TTAA within Audit Note AN16 had been that an incremental / absolute growth methodology needed to be adopted to ensure that the future year matrices within the local area models maintained the TMfS growth distribution. It was recognised that the incremental / absolute approach would potentially result in excessive growth and that, as with Jacobs-Arup's original forecasting methodology, peak spreading and some level of trip restraint were likely to be required.

Audit Note AN17 therefore presented a review of the updated approach now being proposed by Jacobs-Arup.

The review presented in Audit Note AN17 was based on an examination of the following documentation and information received from Jacobs-Arup:

- *Stage 3 Paramics Modelling – Future Year Demand Methodology – Alternative Application of TMfS Absolute Difference Growth Forecasts, Technical Note TN-ST3-P15 Version 5 (17 February 2010).*
- *Stage 3 Paramics Modelling – Future Year Demand Methodology – Alternative Application of TMfS Absolute Difference Growth Forecasts, Technical Note TN-ST3-P15 Version 8 (29 March 2010).*
- *Updated S-Paramics Base Year and 2017 Do Minimum (Do Min) and 2017 With Scheme (Do Some) models (received 8 March & 5 March 2010, respectively).*

The review presented in Audit Note AN17 also took cognisance of discussions between Jacobs-Arup and the TTAA at the meeting held on 12 March 2010 at SIAS's offices in Edinburgh and various email correspondence etc. following the meeting.

Following the issue of Audit Note AN16, Jacobs-Arup responded to the TTAA's concerns by releasing Technical Note TN-ST3-P15 – FRC Alternative Application of TMfS Absolute Difference Growth Forecasts – Versions 5 and 8. (Version 4 was originally issued in Draft prior to being superseded by Version 5 and then later Version 8).

Based on a review of Version 5 of TN-ST3-P15, whilst the TTAA was generally content with the underlying principles of the updated methodology which Jacobs-Arup had applied, a number of concerns were highlighted. The TTAA's main concern regarded the net effects of the forecasting adjustments for cross-Forth traffic, namely:

- peak spreading had reduced the traffic in the first 2 hours and increased traffic in the 2nd 2 hours of the AM peak
- peak spreading had increased the traffic in the first 2 hours and decreased traffic in the 2nd 2 hours of the PM peak
- macro time period choice had moved a lot of traffic to the Inter-Peak
- macro time period choice had a far bigger effect than peak spreading

Additionally, whilst the TTAA accepted that demand would spread to fit the available capacity, there was a limit to how much this assumption held true. For example, in the real world weekday drivers experiencing congestion in the morning peak period would generally retime their journeys to leave earlier and similarly in the evening peak period would retime their journeys to leave later – peak spreading / micro time period choice. It is less likely that weekday drivers travelling to and from work would be able to leave later in the morning and earlier in the evening i.e. it is unlikely that a significant proportion of these drivers could move / spread to the Inter-Peak period - macro time period choice.

The TTAA was of the opinion that this sort of realism ('real world') logic check needed to be taken into account within the adjustment process.

The TTAA also had concerns that the process being applied was removing too much traffic / congestion from the peak periods and that the resulting forecast scenarios contained too little congestion. For example, the complete removal of overcapacity trips on some of the approaches to Newbridge was considered excessive given it was perfectly reasonable to expect some degree of congestion to take place during the peak periods.

The TTAA presented a summary of these concerns to Jacobs-Arup - refer to TTAA's email of 5 March 2010.

In Jacobs-Arup's response to these concerns (email of 5 March) Jacobs-Arup advised that they generally agreed with the points raised by the TTAA and were revisiting both the restraint mechanism and re-profiling mechanism with the aim of deriving "*models that present logical and sensible reflections of how the network scenarios are likely to operate in the future years.*"

The updated restraint mechanism and re-profiling mechanism were presented in Jacobs-Arup's updated Technical Note TN-ST3-P15 - Version 8. Audit Note AN17 presented a review of this updated Technical Note.

6.8 Addressing the Audit Issues & Recommendations Presented in Audit Note AN17

Based on a review of the updated Technical Note TN-ST3-P15 (Version 8), the TTAA remained concerned that a number of the original concerns / issues identified had not been fully or satisfactorily addressed. Of particular concern was that the latest updates and adjustments had resulted in a significant shift of traffic from the first three hours of the morning period to the last hour and from the last three hours of the evening period to the first hour – which for some trips

would reflect a shortening of the working day. Therefore whilst the TTAA accepted that significant efforts had gone in to adjusting the 2017 forecast demand matrices, the TTAA did not consider that the resulting updated forecast demand matrices and profiles satisfied certain basic logic checks.

A summary of the Major Audit Issues and Recommendations presented in Audit Note AN17 is presented below:

> **Audit Issue AN17 AI1:** *The TTAA considers that the outputs of the more detailed microsimulation modelling are potentially more sensitive to the overall level of growth and the "significant growth differential being forecast by TMfS between the Do Minimum and Scheme scenarios and the associated shift in distribution of the 2017 growth". With that in mind it is essential to understand the TMfS growth increments for cross-Forth trips in relation to the level of peak period growth that can reasonably be accommodated in the future year Do Minimum and Scheme scenarios. (Major)*
>
> **Recommendation AN17 R1:** *The TTAA would recommend that, in the case of cross-Forth traffic, the "significant growth differential being forecast by TMfS between the Do Minimum and the Scheme scenarios and the associated shift in distribution of the 2017 growth" should be investigated further. If this is demonstrated to be excessive then appropriate measures should be taken e.g. trip restraint as well as micro / macro time period choice. (Major)*

Within Technical Note TN-ST3-P15 (Version 8) Jacobs-Arup advised that there was a "*significant growth differential being forecast by TMfS between the Do Minimum and Scheme scenarios and the associated shift in distribution of the 2017 growth.*" Jacobs-Arup considered this to be "*one of the key issues with creating future year demand matrices that can realistically be accommodated in the Paramics models*".

Having identified this "*significant growth differential*", the TTAA considered that it would have been useful to have investigated why TMfS was predicting such a difference. Ideally, appropriate measures could then have been taken to address the difference if it was demonstrated to be unrealistic or excessive.

The TTAA advised that it was likely that the growth differential forecast by TMfS between the Do Minimum and Scheme would be down to the modelled differential in cross-Forth travel costs between the FRB and FRC within TMfS. The outputs from the more detailed microsimulation modelling were clearly more sensitive to the absolute scale of the predicted growth than those from the strategic TMfS. Therefore, in applying the TMfS incremental growth to the microsimulation model a review of the assigned flows, speeds, routings etc. within TMfS would be useful in identifying the existence of and reasons behind any significant differences. Such checks would also highlight whether the relative Do Minimum to Scheme differences predicted by TMfS were proportionate and therefore whether the forecast cross-Forth growth levels being predicted by TMfS were reasonable to take forward to the more detailed local model assessment.

Various discussions and meetings took place between Jacobs-Arup and the TTAA to consider the significant growth differential being forecast by TMfS between the Do Minimum and Scheme scenarios and the associated shift in distribution of the 2017 growth. Although Jacobs-Arup agreed to include some adjustments to their overall forecasting methodology (as detailed in their Information Note IN-ST3-P05: FRC Future Year Growth Method Refinement – received by the TTAA on 24 May 2010), these did not involve any adjustment to the growth constraint being applied to cross-Forth trips. Any excess demand would however no longer be re-allocated to the Inter-Peak forecasts.

Whilst the TTAA considered the revised approach to be more appropriate, the TTAA continued to hold the view that there was an ongoing disparity in the scale of adjustments being applied between the Do Minimum and the Scheme which in the TTAA's opinion had the potential to bias any assessment in favour of the Scheme.

In order to test the potential impact of this disparity and to avoid holding up the project, the TTAA agreed to run a sensitivity test based on a further development of the Do Minimum and Scheme models whereby a more consistent demand restraint was applied to both the Do Minimum and Scheme. The results of this sensitivity test are discussed further in Chapter 15.

Therefore whilst Audit Issue AN17 AI1 and Recommendation AN17 R1 were not addressed directly by Jacobs-Arup, the TTAA is satisfied that they have been addressed within the sensitivity tests and further development of the Do Minimum and Scheme models undertaken by the TTAA. The TTAA is therefore generally satisfied that AN17 AI1 and Recommendation AN17 R1 have been addressed.

Confirmation LMAR C18: Although Audit Issue AN17 AI1 was not addressed by Jacobs-Arup, it was addressed within the sensitivity tests undertaken by the TTAA. The TTAA is therefore generally satisfied that Audit Issue AN17 AI1 has been addressed.

Confirmation LMAR C19: Although Recommendation AN17 R1 was not addressed by Jacobs-Arup, it was addressed within the sensitivity tests undertaken by the TTAA. The TTAA is therefore generally satisfied that Recommendation AN17 R1 has been addressed.

Additional Audit Issues raised in Audit Note AN17 included:

> **Audit Issue AN17 AI3:** *Given the information presented in Figure 3.1.1 (and to a lesser extent 3.1.2) the TTAA considers there is scope available to carry out further re-profiling of more of the profiles, particularly in the AM peak period. (Major)*
>
> **Recommendation AN17 R2:** *The TTAA would recommend that a further review of the re-profiling should be carried out to ensure that logical peak spreading is applied where demonstrably possible within the defined peak periods. (Major)*

The TTAA noted that the first step in Jacobs-Arup's revised methodology was to adjust the relevant car trip demand profiles to take into account peak spreading – micro time period choice. The re-profiling was however only applied to Profile 2 (intra-Fife trips). None of the other profiles, including those relating to cross-Forth trips, were subject to any re-profiling during this step.

Whilst the TTAA was content that re-profiling applied to Profile 2 resulted in peak spreading which followed a logical pattern i.e. drivers leaving earlier in the AM period and later in the PM period, the TTAA was of the opinion that there was scope to apply a similar re-profiling to a number of the other profiles, in particular those relating to cross-Forth movements.

Following various discussions and meetings, Jacobs-Arup agreed to update their future year forecasting growth methodology. Details of their updated methodology were presented in Information Note IN-ST3-P05: FRC Future Year Growth Method Refinement (passed to the TTAA 24 May 2010). The revised methodology included much more logical and defendable re-profiling which now extended to 21 profiles as opposed to just Profile 2. The TTAA is therefore satisfied that Audit Issue AN17 AI3 and Recommendation AN17 R2 have been satisfactorily addressed.

Confirmation LMAR C20: The TTAA is satisfied that Audit Issue AN17 AI3 has been satisfactorily addressed.

Confirmation LMAR C21: The TTAA is satisfied that Recommendation AN17 R2 has been satisfactorily addressed.

Audit Note AN17 also raised the following Major issues:

> **Audit Issue AN17 AI4:** *The TTAA considers the macro time period choice appears excessive and that the adjustments to the profiles following the macro time period choice result in illogical trip start and end times which effectively reduce the working day. This is not considered to be the expected response to increased delays and congestion. (Major)*
>
> **Recommendation AN17 R3:** *The TTAA would recommend that a further review of the macro time period choice adjustments is required. This should include a review of the AM and PM peak period cross Forth growth increments forecast by TMfS in relation to the level of growth that could reasonably be accommodated. Consideration should be given to adjusting these increments in a consistent manner prior to applying them to the Base matrices. Logic checks should be carried out to support any changes. (Major)*

The TTAA had concerns that the macro time period choice appeared to be excessive and that subsequent adjustments to the AM and PM peak period profiles being applied following the application of macro time period choice resulted in illogical trip start and end times which effectively reduced / shortened the working day. Hence, re-adjustment of the profiles following macro time period choice was having undesirable impacts in the AM and PM peak periods, resulting in profiles that demonstrated apparently illogical micro time period choice effects.

The TTAA advised that it was essential that the peak period spreading / micro-time period choice was seen to be logical and realistic, and needed to reflect what would generally be the expected response on street, namely that car drivers in the peak periods commuting to and from work would generally leave earlier in the AM period and later in the PM period. It was simply not credible to assume that as a general case such drivers would have the opportunity to leave later in the AM period and earlier in the PM period thus shortening the length of their working day.

The TTAA concluded that only Profile 2 (intra-Fife trips) followed the expected response to an increase in delay / congestion i.e. traffic spreading to the earlier hours in the morning peak period and to the later hours in the evening peak period (albeit to a limited extent). The remaining updated profiles and the overall updated all day profile could therefore not be seen to satisfy certain basic logic checks.

In order to ensure that a robust and defendable methodology could be adopted, the TTAA recommended that rather than apply what were in effect illogical changes to the cross-Forth profiles, the more appropriate approach would be to reconsider the AM and PM peak period cross-Forth growth increments forecast by TMfS and to adjust these in a consistent manner prior to applying them to the Base matrices. Such adjustments could sensibly limit the growth to the available cross-Forth capacities in the AM and PM peak periods, would reduce the level of macro time period choice adjustment and would enable a more sensible micro time period choice adjustment to be reflected. Adjustments to the growth increments would reflect trip restraint which the TTAA considered was a more logical response to increased delays / congestion than the excessive macro time period choice followed by AM / PM peak re-profiling which Jacobs-Arup were currently applying. The trip restraint approach would also satisfy basic logic checks which the current macro time period choice followed by AM / PM peak re-profiling approach did not.

As outlined above, Jacobs-Arup agreed to include some adjustments to their overall forecasting methodology (as detailed in their Information Note IN-ST3-P05: FRC Future Year Growth Method Refinement - passed to the TTAA 24 May 2010). This included a review of how to deal with any excess demand and incorporated adjustments to the Inter-Peak expansion factors along with revisions to 21 profiles. However, the TTAA also agreed to run a sensitivity test / further development of the Do Minimum and Scheme models whereby a more consistent demand restraint was applied to both the Do Minimum and Scheme. The results of this sensitivity test are discussed further in Chapter 15.

Therefore whilst the TTAA does not consider that Audit Issue AN17 AI4 and Recommendation AN17 R3 were fully addressed directly by Jacobs-Arup, the TTAA is however satisfied that they have been fully addressed within the sensitivity tests undertaken by the TTAA. The TTAA is therefore generally satisfied that AN17 AI4 and Recommendation AN17 R3 have been addressed.

Confirmation LMAR C22: Although the TTAA does not consider that Audit Issue AN17 AI4 was fully addressed directly by Jacobs-Arup, it was addressed within the sensitivity tests undertaken by the TTAA. The TTAA is therefore generally satisfied that Audit Issue AN17 AI4 has been addressed.

Confirmation LMAR C23: Although the TTAA does not consider that Recommendation AN17 R3 was fully addressed directly by Jacobs-Arup, it was addressed within the sensitivity tests undertaken by the TTAA. The TTAA is therefore generally satisfied that Recommendation AN17 R3 has been addressed.

In addition to the Major Audit Issues and Recommendations discussed above, a number of Medium and Minor Audit Issues were also presented in Audit Note AN17. The TTAA is however generally satisfied that each of these has either been addressed in the updated forecasting methodology and / or is no longer applicable.

Confirmation LMAR C24: The TTAA is generally satisfied that all the Audit Issues identified in Audit Note AN17 have been satisfactorily addressed given the updated forecasting methodology approach adopted.

6.9 Do Minimum & Scheme Network Coding Review

During the review and discussions surrounding the future year demand methodology, the TTAA undertook a high level review / comparison of the updated model networks received from Jacobs-Arup, namely: Base, Do Minimum, Scheme and Scheme + ITS. The comparisons included:

- Base to Do Minimum
- Do Minimum to Scheme
- Scheme to Scheme plus ITS

These comparisons highlighted a number of inconsistencies between the networks. Of particular concern to the TTAA was the fact that there were differences, between for example the Do Minimum and the Scheme, in areas of the modelled networks which should generally have remained unchanged i.e. the only differences between these networks should have been confined to the proposed scheme.

Although a large number of the differences were relatively minor, they suggested that the networks had been coded in parallel rather than in series. Good practice would normally see the Do Minimum coded from a copy of the finalised Base, and the Scheme coded from a copy of the finalised Do Minimum etc. This ensures that the only differences between the networks are

those specifically related to either the Do Minimum or the Scheme as appropriate. The comparison of the Scheme and Scheme plus ITS models did however show that the basic networks were identical and that the only differences identified were those directly associated with the ITS itself which suggested that good practise had been followed here.

An initial list of the network differences identified by the TTAA was emailed to Jacobs-Arup on 7 April 2010. A large number of the network differences identified were relatively minor and were not expected on their own to have a significant impact on the operation of the models. However, others, such the approach gradients to the FRC and the headway factor on the new crossing, were considered by the TTAA to be more serious and could potentially have a more significant impact on the operation of the models.

Jacobs-Arup responded to the network differences identified by the TTAA in their Information Note IN-ST3-P03: Response to TTAA Model Review (8 April 2010). Whilst the TTAA was content with some of the explanations presented in the Information Note, full agreement could not be reached on which of the network inconsistencies and issues highlighted needed to be fully addressed. It was therefore agreed that the TTAA would carry out a series of sensitivity tests based on a further development of the Do Minimum and Scheme models which would address the various network inconsistencies etc. identified. A discussion of these sensitivity tests is presented in Chapter 7.

7 SENSITIVITY TESTS / FURTHER DEVELOPMENT OF DO MINIMUM & SCHEME MODELS

7.1 Introduction / Background

As outlined above, the TTAA and Jacobs-Arup were unable to reach full agreement on the best way to take forward the forecasting or the Do Minimum and Scheme model network updates.

Whilst Jacobs-Arup had agreed to make a number of updates to their forecasting methodology, and had taken on board some of the TTAA's recommendations and advice, they did not fully agree with a number of the TTAA's concerns, namely:

1. the application of peak spreading associated with the forecast matrices
2. the disparity of demand adjustments between the Do Minimum and Scheme forecast matrices
3. the lack of network consistency between Do Minimum and Scheme
4. various elements of the Scheme network coding

Given the difference in professional opinion between the TTAA and Jacobs-Arup regarding which issues should be addressed, and to what extent, a meeting was called between the TTAA, Jacobs-Arup and Transport Scotland to agree the best way forward.

At this meeting, held on 23 April 2010, Jacobs-Arup agreed to partially update their forecasting methodology and to address a limited number of the network coding issues identified by the TTAA. Independently the TTAA would take the development of the Do Minimum and Scheme models a step further by addressing in full the issues and concerns outlined above. The TTAA would then run a series of sensitivity tests which would include a comparison of the outputs from the Jacobs-Arup model runs and the TTAA model runs to determine the extent of any differences e.g. traffic flows, queuing etc. and to determine the overall impact of not addressing the TTAA's concerns.

The primary objective of the sensitivity tests was to ensure that the Jacobs-Arup models would stand up to scrutiny and whether not fully addressing the TTAA's concerns was likely to result in significantly different answers e.g. different flows, travel times, etc.

As part of these sensitivity tests the TTAA would also review Jacobs-Arup's Active Traffic Management (ATM) measures, which included Intelligent Transport Systems (ITS) proposals, and amend these if considered necessary.

It was agreed that the results of the sensitivity tests would be presented in the Local Area S-Paramics Modelling Audit Report.

7.2 TTAA's Updates to the Forecasting Methodology, Networks & ATM Scenarios

The TTAA carried out a number of updates to the forecasting methodology as well as addressing the Do Minimum and Scheme network anomalies etc. identified. A summary of the updates carried out by the TTAA is presented below:

1. *Demand Restraint:* a revised approach was adopted to constrain the 2017 demand matrices being forecast by TMfS. This removed the disproportionate restraint which the Jacobs-Arup approach resulted in i.e. where far more demand was being removed from the Scheme than the Do Minimum.
2. *Micro Time Period Choice:* the Jacobs-Arup approach to micro time period choice (peak spreading) involved a combination of profile adjustments and the transfer of trips into the interpeak period which had the effect of shortening the working day. The TTAA adopted a different approach to peak spreading and applied the incremental logit

model outlined in DMRB Vol. 12 (Section 2, Part 1, Appendix F). This was applied in an incremental manner for a range of profiles.

3. *Network Adjustments:* the TTAA had identified a number of network coding issues and a number of inconsistencies between the coding of the Scheme network and the Do Minimum. Whilst Jacobs-Arup agreed to correct some of these agreement could not be reached on the full list of corrections / updates required. The TTAA therefore elected to address what were considered to be the most significant coding issues identified in the Do Minimum and Scheme networks and to ensure the networks were as consistent as possible.
4. *Network Optimisation:* having made adjustments to the demands, profiles and networks the TTAA's updated 2017 Do Minimum and Scheme models were run and their operation assessed. Where necessary amendments to the networks were made e.g. modification to signal timings, stop-line positions etc. Limited modifications were made to both the Do Minimum and Scheme models as required.

Full details of the updates carried out by the TTAA are presented in the Technical Note TN1: TTAA Adjustments to 2017 Do Minimum & Scheme Models (29 September 2010, Ref. 73151), a copy of which is included in Appendix A.

In addition, the TTAA also updated the ATM scenarios proposed by Jacobs-Arup. The TTAA's review of the Jacobs-Arup ATM coding etc. had found that ATM speed limit reductions were being introduced when there was no congestion on the network. As a result, the TTAA revised the ATM settings and introduced updated scenarios aimed at improving the ATM calibration and avoiding speed limit reductions being introduced when there was no congestion.

Full details of the TTAA's review of the Jacobs-Arup ATM settings / ITS models, along with the TTAA's proposed updates etc., are presented in the TTAA's Audit Note: FRC: Audit of ITS Model (issued separately to this Local Model Audit Report).

7.3 Comparison of the Jacobs-Arup Model Runs & the TTAA Model Runs

Having updated the Do Minimum and Scheme models to take on board the updates outlined above, the TTAA ran a series of comparisons of these models against the equivalent Jacobs-Arup models. A summary of these comparisons is presented below.

Based on the comparison of the TTAA Do Minimum and Scheme models (including ITS) against the equivalent Jacobs-Arup models, the following flow and congestion differences etc. were noted - see also Appendix B where tabulated comparisons are presented:

1. The updated TTAA models show more congestion both north and south of the bridge in both the Do Minimum & Scheme.
2. Average AM and PM network speeds in the TTAA models are slower than the equivalent speeds in the Jacobs-Arup models e.g. Do Minimum AM 27.2mph v 34.4 mph; PM 24mph v 27.2mph; Scheme AM 29.1mph v 37.3mph; PM 25.4mph v 28.2mph. The average network speeds in the Inter-Peak are very similar.
3. Average global network journey times show similar changes between the TTAA models and the Jacobs-Arup models e.g. Do Minimum AM 13.3min (TTAA) v 10.4min (Jacobs-Arup); IP 9.4 min v 9.4min; PM 14.4min v 12.5min; Scheme (inc. ITS) AM 13.1min (TTAA) v 10.1min (Jacobs-Arup); IP 9.7min v 9.8min; PM 14.2min v 12.7min. The TTAA models therefore show reductions in average journey times with the Scheme (inc. ITS) in place compared to the Do Minimum in the AM and PM peak periods and an increase in journey time in the Inter-Peak period. The Jacobs-Arup models however show a reduction in average journey time for the Scheme compared to the Do Minimum in the AM period but an increase in both the PM and Inter-Peak periods which seems less intuitive.

4. The TTAA models contain more traffic compared to the Jacobs-Arup models e.g. Do Minimum AM +2184; PM +4697; +2.1% across the full day; and Scheme (inc. ITS) AM +1886; PM +4698; +2% across the full day.
5. The TTAA models have more traffic using FRC e.g. +934 vehicles n/b & +1504 veh s/b (across the 14 hour period h/b 0600-1900). The TTAA Scheme models show changes along the A904 of +387 e/b & -116 w/b; along the B924 Bo'Ness Road in South Queensferry (near to Echline Corner) of +9 veh n/b & -6 s/b; along A90 east of the M9 spur +150 e/b & -625 w/b; and on the M9 spur +1053 n/b and +1380 s/b.
6. The main flow differences generally occur towards the end of the morning peak period (h/b 0900) and after the evening peak period (h/b 1900) particularly across the FRC. However, across the morning and evening peak periods (h/b 0700-0900 & h/b 1600-1800) the overall differences in flows between the TTAA models and the Jacobs-Arup models across the Forth are less than 5.2%.
7. The largest percentage difference in peak period flows with the Scheme in place is eastbound along the A904 during the PM peak period where the TTAA models show a 22% increase over the equivalent Jacobs-Arup models. However, this only equates to an increase of 334 vehicles across a three hour period.
8. In the Do Minimum the TTAA models show higher levels of congestion / queuing in the AM period on the M90 north of the bridge with s/b queuing reaching Halbeath earlier in the period than the Jacobs-Arup models. In the PM period the TTAA models show more queuing south of the bridge than the Jacobs-Arup models.
9. The TTAA Scheme models show increased levels of queuing throughout the modelled network. On the M90 s/b in the AM period the TTAA models show much more queuing compared to the equivalent Jacobs-Arup models with the s/b queues in the TTAA model reaching Halbeath. There are also higher levels of congestion and queuing at Barnton in the TTAA model.
10. In the PM period the TTAA models show higher levels of congestion on the FRC than the Jacobs-Arup models e.g. between 17:30 & 18:00 the Jacobs-Arup models show no queues on the FRC. Additionally, the TTAA models show queues on the approaches to the M90 i.e. from Dalegety Bay and around Inverkeithing, as well as increased queuing and congestion south of the FRC compared to the Jacobs-Arup models, particularly around Newbridge.
11. Throughout the day the TTAA models show various levels of queuing in and around Rosyth, Kirkliston, Inverkeithing as well as at Newbridge and along Queensferry Road out of the city etc. The Jacobs-Arup models generally show considerably less queuing in these areas.
12. Based on the summary statistics and the comparisons of congestion, the TTAA models are expected to show higher benefits associated with the Scheme along the main M90 corridor and elsewhere, as there are higher levels of congestion in the Do Minimum which are being reduced / removed.

Whilst the global journey times are similar between the TTAA models and the Jacobs-Arup models, a comparison of the journey times for traffic using the FRC shows some considerable differences. For example, in the PM period the journey time between the M9 Junction 1a and Halbeath can differ by over 12 minutes for the scheme including ITS and 16 minutes for the Scheme excluding ITS. Table 15.1 below presents a summary of journey times between Halbeath and M9 Junction 1a, near Kirkliston

Northbound, JTs in mins

Journeys	Do Minimum			Scheme			Scheme ITS		
Starting	Jacobs	TTAA	Diff	Jacobs	TTAA	Diff	Jacobs	TTAA	Diff
06:00	10.9	10.9	0.0	11.3	11.4	0.1	11.3	11.4	0.1
07:00	11.5	11.4	-0.1	12.2	12.6	0.4	12.3	13.0	0.7
08:00	12.1	12.0	-0.1	13.6	15.6	2.0	13.4	15.9	2.5
09:00	11.8	11.5	-0.2	12.4	14.6	2.2	12.2	15.0	2.8
10:00	11.3	11.3	0.0	11.6	12.2	0.6	11.7	12.9	1.2
11:00	11.1	11.1	0.0	11.5	11.7	0.2	11.5	12.1	0.6
12:00	11.1	11.1	0.0	11.5	11.7	0.2	11.5	12.1	0.6
13:00	11.2	11.2	0.0	11.5	11.8	0.3	11.6	12.4	0.8
14:00	11.4	11.3	-0.1	11.7	12.1	0.4	11.8	12.8	1.0
15:00	11.1	10.9	-0.1	11.5	11.8	0.2	11.5	12.3	0.8
16:00	13.9	16.0	2.1	13.4	15.8	2.4	13.0	16.0	3.0
17:00	15.3	24.1	8.8	12.7	21.5	8.7	12.5	20.3	7.8
18:00	12.1	24.8	12.7	11.1	27.0	16.0	11.1	23.7	12.6

South, JTs in mins

Journeys	Do Minimum			Scheme			Scheme ITS		
Starting	Jacobs	TTAA	Diff	Jacobs	TTAA	Diff	Jacobs	TTAA	Diff
06:00	13.0	15.8	2.8	12.6	14.8	2.2	12.5	14.6	2.1
07:00	23.8	36.1	12.3	20.6	27.6	7.0	20.0	27.8	7.9
08:00	24.5	28.8	4.3	23.6	23.8	0.2	22.3	23.5	1.2
09:00	13.5	17.6	4.2	12.2	14.6	2.3	11.9	14.5	2.7
10:00	11.4	12.4	1.0	11.7	11.5	-0.2	11.6	11.7	0.1
11:00	11.0	11.0	0.0	11.3	11.2	-0.1	11.3	11.3	0.0
12:00	11.4	11.4	0.0	11.5	11.3	-0.2	11.5	11.4	-0.1
13:00	11.5	11.5	0.1	11.6	11.4	-0.3	11.6	11.6	0.0
14:00	11.9	11.8	-0.1	11.8	11.6	-0.3	11.8	11.8	0.0
15:00	11.4	11.4	0.0	11.7	11.5	-0.1	11.6	11.7	0.1
16:00	13.2	13.6	0.5	12.8	12.8	0.0	12.5	13.2	0.7
17:00	26.8	29.6	2.8	21.5	23.2	1.7	20.4	23.6	3.2
18:00	24.4	28.4	4.0	20.5	22.0	1.5	16.9	22.3	5.4

Table 15.1: Comparison of Journey Times Between Halbeath and M9 Junction 1a

As can be seen from Table 15.1 the absolute journey times between Halbeath and the M9 Junction 1a are very different between the TTAA and the Jacobs-Arup models especially in the PM period. While the Do Minimum to Scheme trends are similar (and this is unlikely to significantly affect for example the emission modelling results given the greatest impact on these will be due to the increase in travel distance), it does demonstrate that the "picture" and therefore the operational conditions presented by the two sets of models are at times very different.

Based on the summary analysis presented above it would appear that the Jacobs-Arup models are presenting a more optimistic view of the network operating conditions in 2017 compared to the equivalent TTAA models. These differences tend to be masked by the global comparisons but become more obvious when more focused comparisons are undertaken.

Tabulated summaries of the Network Statistics and flow comparisons for the TTAA models and the Jacobs-Arup models are presented in Appendix B.

The TTAA models can be considered the final phase of the development of the Do Minimum and Scheme models and are essentially a refinement of the Jacobs-Arup models. However, given the differences between the TTAA and Jacobs-Arup Do Minimum & Scheme models outlined above, the further developments and refinements associated with the TTAA models

appear to have resulted in what can be considered to be a more intuitively realistic representation of the expected future traffic conditions (i.e. significant congestion exists on the approaches to the existing Forth Crossing at present and this would be expected to worsen with traffic growth over time).

As the TTAA models contain what can be considered to be more realistic levels of congestion and higher levels of cross Forth traffic, the TTAA would recommend that these models are taken forward for any future local operational, economic and environmental analysis.

Recommendation LMAR R1: The TTAA would recommend that the final versions of the Do Minimum and Scheme models (i.e. those which fully address the various Audit Issues identified by the TTAA) are used for any future local operational, economic and environmental analysis.

As outlined above, the TTAA models show increased southbound queuing on the M90 extending as far back as Halbeath. Given Halbeath is the edge of the ITS network this suggests that additional ITS signing may be required to ensure sufficient advance warning of downstream queuing. The TTAA would therefore recommend that a review of the ITS signing strategy is carried out. Discussed further in the TTAA's Audit Note: FRC: Audit of ITS Model (issued separately to this Local Area Model Report).

Recommendation LMAR R2: The TTAA would recommend that a review of the ITS signing strategy is carried out given the southbound queuing on the M90 in the TTAA Scheme models potentially extends as far as Halbeath i.e. the edge of the ITS network. (Discussed further in the TTAA's Audit Note: FRC: Audit of ITS Model)

8 AUDIT NOTE AN13: REVIEW OF JACOBS-ARUP'S DO MINIMUM MAINTENANCE & CONSTRUCTION IMPACTS ECONOMIC EVALUATION (30 SEPTEMBER 2009)

8.1 Introduction

During the development and updating of the FRC local area Paramics models discussed above, due to the timescales being imposed on the study it was necessary for Jacobs-Arup to undertake local area environmental and economic assessments using the models which were currently available. The local area assessments included sensitivity tests associated with the Whole Life Maintenance Impacts and Construction Impacts associated with the Do Minimum and Scheme networks. The results from these sensitivity tests were fed into the overall economic and environmental assessments to provide an indication of the potential local impacts. They were also used to provide supplementary economic indicators in support of the core values e.g. core Benefit to Cost Ratio (BCR) etc.

Jacobs-Arup and Transport Scotland were aware that the local area models being used at this point in the assessment had not been audited. Furthermore the Do Minimum and Scheme models had not been developed from fully calibrated and validated Base models i.e. they were developed from the Phase 2 Base models – refer to Chapter 4. Using these early models therefore represented a risk, albeit a calculated risk, should the audit highlight any major areas of concern or more particularly any areas where the assigned flows etc. significantly changed between the early versions of the models and the later more fully developed and fully audited models.

Jacobs-Arup and Transport Scotland were advised of the risks associated with using the early models. However, given the outputs from the early models were only being used to supplement the wider area economic and environmental assessments, the risk was not considered excessive. For example, the local economic impacts associated with the Whole Life Maintenance and Construction Impacts only contributed around 10% to the overall economic benefits – the other 90% coming from the strategic assessment. The outputs were however expected to give a reasonable indication of the local area impacts. Provided no specific decisions were being made or based on the outputs from these early models, and the results etc. were only ever considered indicative, the use and application of these early was considered acceptable.

In the case of the assessment of the Whole Life Maintenance Impacts and the Construction Impacts which were carried out using the early versions of the Do Minimum and Scheme models, the economic benefits and costs associated with these were used to supplement the overall core TMfS / TUBA economic evaluation of the Forth Replacement Crossing scheme – refer DMRB Stage 3 Reporting published in November 2009. The TTAA was therefore asked to review the basic methodology adopted to ensure it was robust and defendable. The intention would then be to update the assessment at a later point, once the updated Do Minimum and Scheme models developed from the recalibrated and revalidated Base models, were available should this be considered necessary i.e. if large differences between the different models were found.

8.2 Information Reviewed

The review presented in Audit Note AN13 was based on an examination of the following documentation and files received from Jacobs-Arup, which cover three separate modelling exercises:

- *Stage 3 Paramics Modelling – Main Cable Replacement Delay Assessment – Technical Note TN-ST3-P08-Draft (10 June 2009)*
- *Stage 3 Paramics Modelling – Scheme Construction Delay Evaluation, Technical Note TN-ST3-P09 (28 July 2009)*

- *Stage 3 Paramics Modelling – Do Minimum Maintenance (Whole Life) Economic Evaluation – Technical Note TN-ST3-P10 Version 1 (13 August 2009)*
- *Example copies of the Whole Life Maintenance PEARS input files (24 August 2009)*

Although each of the three Technical Notes listed above dealt separately with different aspects of the Stage 3 economic modelling, the general methodology and modelling approach was consistent throughout and the same models had been used. Therefore the comments etc. presented by the TTAA in Audit Note AN13 were generally applicable to all three Technical Notes and all three modelling exercises. However, specific comments on each of the Technical Notes were presented as required.

As outlined, the early Whole Life Maintenance Impact and the Construction Impact economic evaluations only contributed around 10% to the overall economic assessment, and given the assessments would potentially be repeated once new models had been developed, based on the recalibrated and revalidated Phase 5 Base models, the TTAA's review presented in Audit Note AN13 focussed on the general approach adopted and the methodologies applied, as opposed to any detailed review of the actual modelled networks etc. or the actual numbers presented.

8.3 Audit Note AN13 – Audit Issues & Recommendations

Based on a review of the information etc. outlined above, a number of Audit Issues and Recommendations were identified by the TTAA and presented in Audit Note AN13. The majority of these were however considered to be only Medium or Minor in nature. The Major Audit Issues identified by the TTAA were that the forecast matrices had been derived using the Furnessing growth methodology and that a blanket reduction in overall traffic levels appeared to have been applied, namely:

> **Audit Issue AN13 AI4:** *Assuming the 2017 forecast matrices have been derived using the Furnessing growth methodology the TTAA wish to highlight the potential concerns raised in Audit Note AN12 Audit Issue 2. (Major)*
>
> **Audit Issue AN13 AI7:** *The TTAA notes that the naming of the log runs associated with the Whole Life Maintenance Impact models suggests that these have been run with 85% demand. Clarification is sought on exactly what level of demand has been used in the WLMI assessments. (Major)*

8.4 Audit Note AN13 – Confirmations

However, in addition to the Audit Issues identified in Audit Note AN13, the following Confirmations associated with the Whole Life Maintenance Impact and the Construction Impact assessments were also presented::

Confirmation AN13 C1: The TTAA is satisfied with the general approach taken to determine a realistic delay on the FRB associated with the Main Cable Replacement and that the subsequent delay used within the TMfS / TUBA assessments was reasonable and defendable.

Confirmation AN13 C2: The TTAA is generally content with the overall methodology and approach adopted to asses the Construction Impacts.

Confirmation AN13 C3: The TTAA is satisfied that there is no need to assess any maintenance works carried out overnight as the expected traffic flows are lower than the capacity offered by any contra flow and therefore delays would be minimal.

Confirmation AN13 C4: The TTAA is generally content with the overall methodology and approach adopted to asses the Whole Life Maintenance Impacts.

Confirmation AN13 C5: The TTAA is generally content that the Whole Life Maintenance PEARS input files appear reasonable and that the outputs from the files examined are being correctly reported.

8.5 Audit Note AN13 – Conclusions

When Audit Note AN13 was issued, the TTAA advised that whilst generally content with the overall methodology and approach adopted, there were areas of the assessment which were considered extremely coarse e.g. a blanket matrix reduction was applied as opposed to a reduction focussed only on cross-Forth movements. Furthermore, the models being used to run the assessment had not been fully developed or fully audited i.e. the Do Minimum and Scheme models had not been developed from fully calibrated and validated Base models. The Do Minimum and Scheme models also incorporated a forecast methodology which included Furnessed growth which had been demonstrated to alter the trip distributions between the strategic (TMfS) and local models – as discussed in Audit Note AN12 etc. above.

The results of the Whole Life Maintenance Impact and the Construction Impact assessments could therefore only be considered indicative of the maintenance and construction benefits which could be expected to occur with the new bridge in place. The TTAA did however recognise that the Whole Life Maintenance Impact and the Construction Impact benefits were not so significant that they could be seen as a key factor in determining the overall economic value of the new crossing i.e. they only contributed around 10% of the overall economic benefits attributed to the proposed scheme. Furthermore, any updated local benefits are expected to increase / add to the overall benefits attributed to the scheme.

When Audit Note AN13 was issued in September 2009, the TTAA's principal Recommendation was that when updated Do Minimum and Scheme models were available the economic assessment of the Whole Life Maintenance and Construction Impacts should ideally be repeated / updated taking account of the various Audit Issues and Recommendations. This would ensure that the most up to date models were being used and that the assessment was as robust as possible. The principal Recommendation associated with the assessment of the Whole Life Maintenance and Construction Impacts was therefore:

> **Recommendation AN13 R4:** *The TTAA would recommend, that when the updated Do Minimum and Scheme models are available, the development of the weekend matrix should be updated taking into account the weekend trip distributions, vehicle compositions and directional flows. The Whole Life Maintenance Impacts and the Construction Impacts analysis should then be updated. (Major)*

No formal response was received from Jacobs-Arup regarding the Audit Issues and Recommendations presented by the TTAA in Audit Note AN13. However, in discussions between the TTAA and Jacobs-Arup in November 2010, Jacobs-Arup indicated that if the assessment of the Whole Life Maintenance and Construction Impacts were repeated this would be done using the final versions of the updated Do Minimum and Scheme models. Jacobs-Arup also confirmed that they would use updated models to test any future traffic management arrangements proposed during the construction and maintenance of the new crossing and the maintenance of the existing crossing.

As part of any updated assessments, Jacobs-Arup advised that they would also address as far as possible the various Audit Issues etc. identified by the TTAA in Audit Note AN13. For example, it may not be possible to fully develop a weekend matrix given the lack of weekend trip distribution data.

The TTAA understands that no further re-assessment of the Whole Life Maintenance and Construction Impacts has been undertaken to date (March 2011). As a result, the Audit Issues and Recommendations presented in Audit Note AN13 remain outstanding. The TTAA however accepts that the impact on the overall scheme assessment of using the results / benefits etc. based on the early assessments of the Whole Life Maintenance and Construction impacts i.e. those derived from the non-approved models, would be relatively small. Furthermore, any updated Whole Life Maintenance and Construction assessments are expected to result in increased the local benefits which will increase / add to the overall benefits attributed to the scheme. The overall scheme assessment to date can therefore be seen to be erring on the side of caution.

The TTAA would however reiterate that any future testing of traffic management arrangements proposed during the construction and maintenance of the new crossing and the maintenance of the existing crossing, along with any future assessment or development of the ITS strategy etc. should be carried out using suitably updated local area models (refer to Recommendation LMAR R1).

9 SUMMARY & CONCLUSIONS – LOCAL AREA MODEL AUDIT REPORT

9.1 Summary

SIAS Limited (SIAS), as part of the Transport Scotland's Traffic and Transport Advisor and Auditor (TTAA) commission, has undertaken a review of Jacobs-Arup's local area S-Paramics modelling associated with the traffic, economic and environmental assessment of the Forth Replacement Crossing.

The local area modelling was based on the development and application of an S-Paramics microsimulation model. The area covered by the local area model was primarily confined to the Forth Crossing corridor.

The primary objectives of the local area S-Paramics models can be summarised as follows:

- *Operational Assessment:* the models are to be used to assess the more detailed operational aspects of the proposed scheme including the Active Traffic Management (ATM) proposals.
- *Economic Assessment:* the models are to be used to estimate the economic impacts associated with the whole life maintenance of the existing and proposed crossings, along with the construction impacts associated with the proposed new crossing. The benefits associated with the Active Traffic Management (ATM) proposals are also to be assessed using the local area models.
- *Environmental Assessment:* the local area S-Paramics models are also to be used to assess the emissions impacts associated with the proposed scheme, including the proposed ATM measures, in more detail than was possible using the strategic model

The economic impacts associated with the whole life maintenance, construction and ATM derived using the local model will be used to supplement the wide area strategic impacts and core economics determined using the strategic TMfS model. Similarly, the environmental impacts derived using the local model will be used to supplement the wide area strategic impacts and core environmental / emissions analysis determined using the strategic TMfS model

This Local Area Model Audit Report includes the TTAA's review of the following Audit Notes issued throughout the development and review of the local models:

- *Modelling Audit Note AN1 (20 October 2008, Ref. 70422)*
- *Audit Note AN5: Stage 3 S-Paramics Model Network Review (5 Dec 08, Ref.. 70614)*
- *Audit Note AN6: 2008 Base Model Development & validation (23 Dec 08, Ref. 70679)*
- *Audit Note AN7: Stage 3 S-Paramics Model Development & Calibration Review (26 May 09, Ref. 71386)*
- *Audit Note AN8: Stage 3 S-Paramics Model Matrix Development Methodology Review (3 June 09, Ref. 71434)*
- *Audit Note AN10: Review of Jacobs-Arup Responses to Audit Note AN7 & FRC Stage 3 Paramics Model Development Report (29 June 09, Ref. 71530)*
- *Audit Note AN12: Review of Jacobs-Arup's Stage 3 Modelling – Future Year Traffic Forecast Development Methodology (24 Sept 09, Ref. 71869)*

- *Audit Note AN13: Review of Jacobs-Arup's Do Minimum Maintenance & Construction Impacts Economic Evaluation (30 Sept 09, Ref. 71870)*
- *Audit Note AN15: Stage 3 S-Paramics Base Model Final Review (4 Dec 09, Ref. 72204)*
- *Audit Note AN16: Review of Jacobs-Arup's Responses to AN12 and Stage 3 Paramics Modelling – Future Year Traffic Forecast Methodology (11 Dec 09, Ref. 72213)*
- *Audit Note AN17: Review of Jacobs-Arup's Updated Stage 3 Paramics Modelling – Future Year Demand Methodology – Alternative Application of TMfS Absolute Difference Growth Forecasts (21 April 10, Ref. 72684)*

The TTAA's review of the FRC local area modelling was carried out over an extended period and was based on an examination of the different development phases of the Base, Do Minimum and Scheme models. The review also examined the Active Traffic Management (ATM) models. Furthermore, the review examined the approach and methodology adopted to assess of the Whole Life Maintenance Impacts and Construction Impacts, the outputs of which are being used to supplement the overall strategic TMfS / TUBA based economic assessment.

The TTAA's review also included running a series of sensitivity tests based on a further development of the Jacobs-Arup Do Minimum and Scheme models. The TTAA's further developments included an alternative forecasting methodology as well as additional network updates and corrections. A comparison of the TTAA models against the equivalent Jacobs-Arup models was undertaken in terms of differences in traffic flows, congestion and journey times.

In the TTAA's review of the local area modelling analysis carried out by Jacobs-Arup, the TTAA identified a number of Audit Issues and made a number of Recommendations. A number of Confirmations were also presented regarding areas of the Jacobs-Arup local area modelling analysis which the TTAA was content with. Where Jacobs-Arup responded to the various Audit Issues and Recommendations, any such responses were considered by the TTAA and provided the TTAA was satisfied with the responses received Confirmations were given advising that the Audit Issues and Recommendations had been satisfactorily addressed.

9.2 Conclusions

The Base model development was undertaken in five distinct phases as described earlier in this report. During the early phases i.e. Phases 1 and 2, the TTAA identified a number of issues and concerns regarding the development and calibration of the Base model leading to a number of recommendations for improvement. These issues were satisfactorily addressed during the later phases of the Base model development, Phases 3 to 5.

As regards to the forecasting undertaken, the TTAA is generally satisfied that the final versions of the local area models developed by Jacobs-Arup are reasonably robust and are reasonably fit for the purpose of undertaking some aspects of the local area modelling assessments e.g. the emissions analysis. The Jacobs-Arup models do however show relatively low levels of queuing and congestion in future years and relatively low cross-Forth journey times compared to the TTAA models. It is likely therefore that the Jacobs-Arup models will potentially underestimate any economic or operational impacts / benefits associated with the scheme as well as any potential emissions reductions associated with the introduction of ATM / ITS. A degree of care is therefore needed when interpreting outputs from these models.

The TTAA models, which are essentially a further development of the Jacobs-Arup models and include an alternative forecasting methodology as well as further network updates etc., show intuitively more realistic levels of future year congestion etc.. The TTAA models are therefore considered to be more appropriate than the equivalent Jacobs-Arup models for any further / updated operational or economic assessments.

In both the TTAA and Jacobs-Arup Do Minimum and Scheme models the TTAA identified a number of areas associated with the Inter-Peak matrix development which would benefit from further improvements. This is primarily due to the limited availability of observed Inter-Peak data. As a result, in both the Jacobs-Arup models and the TTAA models, the Inter-Peak period is relatively coarse compared to the equivalent AM and PM periods. A degree of care is therefore needed when interpreting any results which include the less robust Inter-Peak period.

The TTAA is aware that various analysis and reporting has already been carried out to date using early versions of the Do Minimum and Scheme models. For example, the DMRB Stage 3 reporting published in November 2009 included supplementary emissions and economic analysis of the Whole Life Maintenance, Construction and ATM impacts etc. These early models were developed from Base models which had not been audited and which did not satisfy the DMRB acceptability criteria in terms of Base model calibration and validation. Furthermore the forecast matrices applied in these assessments included a Furnessing growth methodology which the TTAA had demonstrated had the potential to significantly alter the trip distributions between the strategic TMfS model and the local area Paramics model. The TTAA would advise that any results or analysis based on these early models contains an element of risk, albeit a small risk overall given the scale of the local impacts relative to the overall strategic impacts - any outputs from these early models need to be treated with a degree of care.

To reduce / remove this risk the TTAA would recommend that any early analysis and reporting, carried out using early versions of the Do Minimum and Scheme models, should ideally be updated based on the most recent models available i.e. those models developed from calibrated and validated Base models etc. This should specifically include the early economic analysis of the Whole Life Maintenance, Construction and ATM impacts etc., reviewed in Audit Note AN13, given none of the Audit Issues or Recommendations presented by the TTAA in Audit Note AN13 were specifically addressed / formally responded to.

Recommendation LMAR R3: The TTAA would recommend that any of the early operational, economic and environmental analysis, carried out using early versions of the local area models, should ideally be updated based on the final versions of the local area Paramics models.

Furthermore, given the TTAA's final development versions of the Do Minimum and Scheme models appear to present an intuitively more realistic representation of the expected future traffic conditions, the TTAA would recommend that any future operational, economic or emissions assessments, including any ATM analysis, are carried out using these versions of the local area Paramics models – see Recommendation LMAR R1.

9.3 Summary of Confirmations Presented in this Local Area Model Audit Report

The following is a summary of the various Confirmations associated with the FRC local area S-Paramics modelling presented within this Local Area Model Audit Report:

Confirmation LMAR C1: The TTAA is generally satisfied that Audit Issues associated with the local area modelling presented in Audit Note AN1 are either no longer applicable and / or have been satisfactorily addressed during the development of the final Base models (released November 2009).

Confirmation LMAR C2: The TTAA is TTAA is satisfied that the Recommendations associated with the local area modelling presented in Audit Note AN1 are either no longer applicable and / or have been satisfactorily addressed during the development of the final Base models (released November 2009).

Confirmation LMAR C3: The TTAA is generally satisfied that Audit Issues associated with the local area modelling presented in Audit Note AN6 are either no longer applicable and / or have been satisfactorily addressed during the development of the final Base models (released November 2009).

Confirmation LMAR C4: The TTAA is TTAA is satisfied that the Recommendations associated with the local area modelling presented in Audit Note AN6 are either no longer applicable and / or have been satisfactorily addressed during the development of the final Base models (released November 2009).

Confirmation LMAR C5: The TTAA is generally satisfied that all the Audit Issues presented in Audit Note AN5 associated with the development of early Base models were satisfactorily addressed during the development of the final Base models (released November 2009).

Confirmation LMAR C6: The TTAA is generally satisfied that all the Recommendations presented in Audit Note AN5 associated with the development of early Base models were satisfactorily addressed during the development of the final Base models (released November 2009).

Confirmation LMAR C7: The TTAA is generally satisfied that all the Audit Issues associated with the Phase 2 local area modelling presented in Audit Note AN7 are largely no longer applicable and / or have been satisfactorily addressed during the development of the final Base models (released November 2009).

Confirmation LMAR C8: The TTAA is generally satisfied that all the Recommendations associated with the Phase 2 local area modelling presented in Audit Note AN7 are largely no longer applicable and / or have been satisfactorily addressed during the development of the final Base models (released November 2009).

Confirmation LMAR C9: The TTAA is generally satisfied that the Audit Issues associated with the Phase 2 Base models and presented in Audit Note AN8 are largely no longer applicable and / or have been satisfactorily addressed during the development of the final Base models (released November 2009).

Confirmation LMAR C10: The TTAA is generally satisfied that the Recommendations associated with the Phase 2 Base models presented in Audit Note AN8 are largely no longer applicable and / or have been satisfactorily addressed during the development of the final Base models (released November 2009).

Confirmation LMAR C11: The TTAA is generally satisfied that the Audit Issues associated with the Phase 2 Base models presented in Audit Note AN10 are largely no longer applicable and / or have been satisfactorily addressed.

Confirmation LMAR C12: The TTAA is generally satisfied that the Recommendations associated with the Phase 2 Base models presented in Audit Note AN10 are largely no longer applicable and / or have been satisfactorily addressed.

Confirmation LMAR C13: The TTAA is generally satisfied that the Phase 5 Base models meet the DMRB acceptability guidelines.

Confirmation LMAR C14: The TTAA is generally satisfied that the Phase 5 Base models are suitable for application to the intended FRC assessment on the strategic road network within the local study area and as the starting point for the development of Do Minimum and Scheme future year models.

Confirmation LMAR C15: The TTAA is generally satisfied that all the Audit Issues identified in Audit Note AN12 have been satisfactorily addressed given the updated forecasting methodology approach adopted.

Confirmation LMAR C16: The TTAA is generally satisfied that all the Audit Issues identified in Audit Note AN16 have been satisfactorily addressed given the updated forecasting methodology approach adopted.

Confirmation LMAR C17: The TTAA is generally satisfied that all the Recommendations identified in Audit Note AN16 have been satisfactorily addressed given the updated forecasting methodology approach adopted.

Confirmation LMAR C18: Although Audit Issue AN17 AI1 was not addressed by Jacobs-Arup, it was addressed within the sensitivity tests undertaken by the TTAA. The TTAA is therefore generally satisfied that Audit Issue AN17 AI1 has been addressed.

Confirmation LMAR C19: Although Recommendation AN17 R1 was not addressed by Jacobs-Arup, it was addressed within the sensitivity tests undertaken by the TTAA. The TTAA is therefore generally satisfied that Recommendation AN17 R1 has been addressed.

Confirmation LMAR C20: The TTAA is satisfied that Audit Issue AN17 AI3 has been satisfactorily addressed.

Confirmation LMAR C21: The TTAA is satisfied that Recommendation AN17 R2 has been satisfactorily addressed.

Confirmation LMAR C22: Although the TTAA does not consider that Audit Issue AN17 AI4 was fully addressed directly by Jacobs-Arup, it was addressed within the sensitivity tests undertaken by the TTAA. The TTAA is therefore generally satisfied that Audit Issue AN17 AI4 has been addressed.

Confirmation LMAR C23: Although the TTAA does not consider that Recommendation AN17 R3 was fully addressed directly by Jacobs-Arup, it was addressed within the sensitivity tests undertaken by the TTAA. The TTAA is therefore generally satisfied that Recommendation AN17 R3 has been addressed.

Confirmation LMAR C24: The TTAA is generally satisfied that all the Audit Issues identified in Audit Note AN17 have been satisfactorily addressed given the updated forecasting methodology approach adopted.

9.4 TTAA's Final Recommendations Presented in this Local Area Model Audit Report

In addition to the Confirmations outlined above, the TTAA would wish to make the following final Recommendations regarding the FRC local area modelling:

Recommendation LMAR R1: The TTAA would recommend that the final versions of the Do Minimum and Scheme models (i.e. those which fully address the various Audit Issues identified by the TTAA) are used for any future local operational, economic and environmental analysis.

Recommendation LMAR R2: The TTAA would recommend that a review of the ITS signing strategy is carried out given the southbound queuing on the M90 in the TTAA Scheme models potentially extends as far as Halbeath i.e. the edge of the ITS network.

Recommendation LMAR R3: The TTAA would recommend that any of the early operational, economic and environmental analysis, carried out using early versions of the local area models, should ideally be updated based on the final versions of the local area Paramics models.

A APPENDIX A – TTAA ADUSTMENTS TO 2017 DO MINIMUM & SCHEME MODELS

Transport Scotland
Forth Replacement Crossing
Technical Note TN1: TTAA Adjustments to 2017 Do Minimum and Scheme Models

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29 September 2010	**Gerard McPhillips**	**TTAA**

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1 TN1: TTAA ADJUSTMENTS TO 2017 DO MINIMUM AND SCHEME MODELS

1.1 Introduction

1.1.1 This paper outlines the process followed by the TTAA to make adjustments to the 2017 Do Minimum and Scheme networks supplied by Jacobs. The models were supplied by Jacobs in an email on 5 March 2010. Following this the TTAA undertook an extensive review of the models and associated documentation supplied by Jacobs. This raised a number of concerns, in particular with respect to the application of peak spreading, the disparity of demand adjustments between the Do Minimum and Scheme, the network consistency between Do Minimum and Scheme and certain elements of the Scheme network coding.

1.1.2 A meeting was subsequently held and while it was acknowledged by Jacobs that they would wish to address some of the identified issues, full agreement could not be reached between the TTAA and Jacobs regarding which issues should be addressed. Therefore Jacobs updated their forecasting methodology and addressed a limited number of the network coding issues identified by the TTAA. Independently, the TTAA addressed those issues which it considered to be relevant to the assessment.

1.1.3 This note outlines the alterations made by the TTAA to Jacobs original 2017 Do Minimum and Scheme networks and the forecasting process.

1.2 Demand Restraint

1.2.1 The TTAA raised the concern that Jacobs' original methodology for restraining cross-Forth demand was restraining demand disproportionately between the Do Minimum and Scheme models (i.e. far more demand was being removed from the Scheme than the Do Minimum). The TTAA therefore took receipt of the original unadjusted matrices from Jacobs and adopted the following methodology to constrain the 2017 demand matrices:

- the cross-Forth demand from the unadjusted matrices for the full AM and PM peak periods by direction was defined
- the assumed practical hourly capacity figures (3,800vph Do Minimum, 4,000vph Scheme) were used to determine what the practical capacity is within the 4 hour AM and PM peak periods

- an adjustment factor of 0.9 was applied to the peak period capacities to reflect the fact that full saturation across 4 successive hours would be unlikely (details of the derivation of this factor are presented below)
- if the unconstrained cross-Forth demand was greater than the peak period capacity (with 0.9 adjustment factor applied) then the values in the relevant cells of the matrices were capped to ensure that the cross-Forth demand was related to the practical infrastructure capacity over the demand period

1.2.2 The issue being addressed with this process was simply the scale of the cross-Forth growth predicted when the TMfS based increment is applied. It is accepted that TMfS as a strategic model is less sensitive to infrastructure capacities than the more detailed local area microsimulation modelling and therefore a demand cap related to the practical peak period capacity was considered to be an acceptable and pragmatic adjustment to apply. No adjustments to the underlying trip distribution were made in this capping process.

1.2.3 It is considered that the key (and defendable) assumptions in this process are that:

- more scope for growth exists in the shoulders of the AM and PM peaks (than in the peak hour) and therefore it is essential to consider the demand / capacity for the entire period and not just the peak hour
- the small amount of additional capacity afforded by the FRC is likely to get "filled up", leading to slightly higher demands with the FRC in place compared with the FRB (as this is effectively what TMfS is implying with the differential in cross-Forth growth between Do Minimum and Scheme)

1.2.4 The 0.9 adjustment factor for the practical cross-Forth capacity was derived by considering the Total Demand flows presented in Jacobs' TN-ST3-P15 Appendix E. The smallest adjustment previously applied (by Jacobs) was a reduction of 204 (over 4 hours) on the AM southbound Do Minimum demand of 13,721. Given such a small reduction the TTAA considered that this was negligible over the full four hour period and would have limited impact. Therefore the original 13,721 forecast demand (from application of the unadjusted TMfS increment) for that movement was considered to be approximately the practical capacity limit for the FRB for the four hour period. Based on Jacobs' earlier analysis the theoretical Do Minimum capacity was determined as 3,800 vehicles per hour or 15,200 across the full four hour period. Therefore comparing the predicted 4 hour practical capacity (13,721) against the 4 hour theoretical capacity (15,200) implied an adjustment factor of 0.9027.

1.2.5 The TTAA therefore derived the cross Forth demand reductions based on applying a 0.9027 adjustment factor to the theoretical four hour capacities i.e. 0.9027 * 4 * 3,800 (Do Minimum) and 0.9027 * 4 * 4,000 (Scheme) – based on the practical hourly capacities previously determined by Jacobs.

1.2.6 The adjustment factor can therefore genuinely be related to the practical and theoretical capacities and can be justified in the absence of anything more technical or detailed at this stage, given the additional resource and timescale implications of a more technical approach.

1.2.7 This process resulted in the following matrix adjustments for the TTAA models:

- PM Peak Do Minimum northbound : Unadjusted = 15,903, Adjusted = 13,721, Reduction = 2,182
- AM Peak Scheme southbound : Unadjusted = 15,464, Adjusted = 14,443, Reduction = 1,021
- PM Peak Scheme northbound : Unadjusted = 17,599, Adjusted = 14,443, Reduction = 3,156

1.2.8 Following initial operational runs of the updated TTAA models a slight anomaly in the matrix totals between the PM Peak Do Minimum and Scheme models was detected. This arose because of boundary effects in the TMfS cordoning between the Do Minimum and Scheme in the PM. The increase in total traffic volumes in the cordon area between the Do Minimum and Scheme (prior to any cross-Forth adjustments) was relatively small in the PM peak. Hence, when the cross-Forth reductions were applied this resulted in the anomalous situation where the Scheme had less traffic overall in the model area compared with the Do Minimum, albeit that cross-Forth volumes were commensurately higher in the scheme. This was not the case with the AM peak.

1.2.9 An investigation of this was undertaken and it showed that boundary effects (e.g. unlikely localised routeing changes) around Newbridge and the south west of the model area resulted in this discrepancy. Accordingly, some additional manual adjustments were made to the TTAA's PM peak period Scheme demands as follows:

Table 1.1 : Additional Local Demand Adjustments – PM Peak Scheme Only

Trip	Origin Zone	Destination Zone	Trips Added
Winchburgh to M9 west	21	18	56
M8 south of Newbridge to M9 west	22	18	178
A8 east of Newbridge to M8 south of Newbridge	25	22	416
Newbridge village to A89 west	24	23	99
A8 east of Newbridge to Newbridge village	25	24	90
M9 west to A8 east of Newbridge	18	25	97
M8 south of Newbridge to A8 east of Newbridge	22	25	149

1.2.10 These are all remote from the scheme, are mainly local movements and the adjustments balance up the exaggerated, local differences between Do Minimum and Scheme predicted by TMfS in the PM.

1.2.11 The net result is a similar global increase in trips (approx. +850) between Do Minimum and Scheme in the PM peak as per the corresponding Jacobs matrices. This is also broadly consistent with the AM peak difference between Do Minimum and Scheme demands. These localised changes have no influence on the operation of the FRC and do not materially change the operational summary statistics for the network, they simply balance up the global difference between Do Minimum and Scheme demands to ensure that they follow an intuitively correct trend.

1.3 Micro Time Period Choice

1.3.1 The TTAA had expressed significant concerns with the methodology adopted by Jacobs to apply micro time period choice (peak spreading). The Jacobs method involved a combination of profile adjustments and the transfer of trips into the inter-peak (macro time period choice) with the net result being that the AM peak profile adjustments had predominantly spread traffic to the hour beginning 0900 while the PM peak profile adjustments had predominantly spread traffic to the hour beginning 1500. This was felt to be an exaggerated/unrealistic response as it effectively implied a general shortening of the working day. While the TTAA recognises that certain trips (e.g. leisure or shopping trips) may respond to increasing congestion by behaving in this way, commuter trips, which form the majority of the car trips in the AM and PM peaks, are

likely to be more constrained by working hours and hence, adjusting departure times to leave for work earlier in the AM peak was considered to be a more likely response for the majority of trips.

1.3.2 The TTAA adopted a different approach to the peak spreading and applied the incremental logit model outlined in DMRB Vol. 12, Section 2, Part 1, Appendix F. This method calculates changes to the profiles based on the difference in cost between the Base Year assignment with the Base profiles and the Future Year assignment with the Base profiles. This was applied in an incremental manner for a range of profiles and involved 10 iterations of the process with 10 runs of the S-Paramics 2017 Do Minimum model in each iteration.

1.3.3 The adjustments were only applied to profiles that controlled >1500 vehicles over the AM peak period. While other profiles could have been adjusted these generally controlled a small amount of traffic and were therefore excluded from the process. The resulting profiles have spread the majority of traffic to earlier in the AM peak period in line with expectations. In some cases a small amount of spreading has occurred in the final hour of the AM peak, however, this is considered reasonable given that the vast majority of peak spreading has occurred earlier in the period.

1.3.4 No peak spreading was applied to the inter or PM peaks. The 2017 profiles adjusted using this process were then taken forward and applied consistently in the Do Minimum and Scheme models. It should be noted that the peak spreading was run using 95% of the full demand. The reason for this is that with 100% demand the initial iterations of the process were gridlocking preventing it from operating successfully while running at 95% enabled the process to complete. The updated profiles were subsequently applied to the Do Minimum and Scheme models running at 100% demand levels.

1.3.5 The profiles modified were:

- Profile 1 Car - General Mway
- Profile 2 Car - North local to local
- Profile 6 Car - A92 to Dunfermline
- Profile 7 Car - A92 to southwest
- Profile 9 Car - Dunfermline to south
- Profile 10 Car - Dunfermline to M90 north
- Profile 14 Car - A921 to south
- Profile 15 Car - A921 to local
- Profile 21 Car - M9 north to M9 south
- Profile 23 Car - Newbridge to north (M9 & M90)
- Profile 24 Car - Newbridge to south
- Profile 25 Car - South residential to north
- Profile 51 Car - General Local
- Profile 55 All - M9 SB to A8

1.4 Network Adjustments

1.4.1 The TTAA had raised various concerns over the coding of the Scheme network and its consistency with the Do Minimum. Following discussions at a meeting on 23 April 2010 the TTAA provided Jacobs with a list of the coding issues that were considered to be the most pertinent and relatively quick to address (ref. email 3 May 2010). While Jacobs acknowledged some of these issues they considered that there was a difference of "professional opinion" regarding others. The TTAA therefore elected to independently address what were considered to be the most significant issues in the FRC network. This included all of the issues outlined in the list of 3 May being addressed as appropriate. As well as addressing the coded error in gradients on the FRC it should be noted that the TTAA networks also included consistent headway factors of 1.25 on both the FRB and FRC, consistency in coding of the relevant signposting distances and consistency in signal staging/timings at the various junctions outlined in the list provided on 3 May. The recoding, to ensure as much consistency as possible, took less than half a day to complete.

1.4.2 The TTAA would note that even with these changes this simply eliminated the most significant inconsistencies identified between the Do Minimum and Scheme networks. The TTAA remains of the opinion that in order to ensure consistency between the Do Minimum and Scheme networks the Do Minimum network should have been fully developed and optimised as far as practicable before proceeding to code the FRC Scheme network. This would have prevented the vast majority of the inconsistencies from arising in the first place which led to the TTAA's concerns being raised.

1.5 Network Optimisation

1.5.1 Having made the relevant changes to the demands, profiles and networks the updated TTAA 2017 Do Minimum and Scheme networks were run and their operation assessed. It was evident that in some runs the Do Minimum and Scheme models were gridlocking in the AM peak period and the reasons for this were assessed. The problems were at the Queensferry Rd/Admiralty Rd/Castlandhill Rd junction in the Do Minimum and on the B981 between Admiralty Rd and Ferrytoll in the Scheme. This led to the following additional optimisation of the networks being undertaken:

Do Minimum Changes

- Southbound visibility of 20m coded on Queensferry Rd approach to Admiralty Rd to assist opposed right turning traffic in congested conditions (same change applied to Scheme)
- Car park capacities in Zone 24 (Newbridge) both set to an equal value to prevent excessive blocking back into one car park and to reflect the fact that if such blocking back did occur in the future traffic would more equally share the 2 possible routes out of the zone (same change applied to Scheme)
- Modifications to traffic signal phasing and timings at Queensferry Rd/Admiralty Rd/Castlandhill Rd junction to maximise throughput and prevent gridlocking in the AM peak 0600-1000 only (same change applied to Scheme)
- Slight adjustment to stacking stopline positions on Admiralty Rd at Queensferry Rd/Admiralty Rd/Castlandhill Rd junction to maximise opposed right turn throughput (same change applied to Scheme)

Scheme Changes

- Modification to signal timings at B981/A921 Chapel Place/Admiralty Rd/North Rd junctions to minimise blocking back to the M90 in the AM peak 0600-1000 only (same change applied to Do Minimum)
- Cycle time at node 2475y changed to 120s to prevent excessive queueing on Hope Street and to make the pedestrian stage call rate more consistent with the Do Minimum (Scheme only, configuration of network is different in Do Minimum)

1.5.2 These changes were sufficient to ensure that the TTAA 2017 Do Minimum and Scheme models ran satisfactorily to produce comparable outputs for the Do Minimum and Scheme networks.

B APPENDIX B – SUMMARY OF NETWORK STATISTICS & FLOW COMPARISONS TTAA MODELS V JACOBS-ARUP MODELS (INCLUDING ATM)

Network Statistics: TTAA v Jacobs Models

TTAA 2017 Do Min

All-day Network	Total Distance (km)	Total Network Time (hours)	Vehicles	Average Network Speed (mph)	Average Journey Time (mins)
Before 10:00	1,059,467	24,161	109,236	27.2	13.3
Between 10:00 and 15:00	1,030,230	17,022	109,232	37.6	9.4
After 15:00	1,089,127	28,216	117,643	24.0	14.4
Full day Simulation	3,178,824	69,399	336,111	28.5	12.4

Jacobs 2017 Do Min

Before 10:00	1,026,786	18,533	107,052	34.4	10.4
Between 10:00 and 15:00	1,029,155	17,046	109,242	37.5	9.4
After 15:00	1,030,795	23,565	112,946	27.2	12.5
Full day Simulation	3,086,736	59,144	329,240	32.4	10.8

TTAA 2017 Scheme Inc. ITS

All-day Network	Total Distance (km)	Total Network Time (hours)	Vehicles	Average Network Speed (mph)	Average Journey Time (mins)
Before 10:00	1,122,041	23,979	110,026	29.1	13.1
Between 10:00 and 15:00	1,080,377	17,715	109,557	37.9	9.7
After 15:00	1,147,864	28,074	118,466	25.4	14.2
Full day Simulation	3,350,281	69,768	338,049	29.8	12.4

Jacobs 2017 Scheme Inc. ITS

Before 10:00	1,088,314	18,123	108,140	37.3	10.1
Between 10:00 and 15:00	1,078,583	17,844	109,563	37.6	9.8
After 15:00	1,090,363	24,065	113,768	28.2	12.7
Full day Simulation	3,257,260	60,031	331,472	33.7	10.9

2017 Flow Comparisons - TTAA v Jacobs

Forth Crossing

	Northbound				Southbound			
	Do Min		Scheme FRC		Do Min		Scheme FRC	
Time h/b	TTAA	Jacobs	TTAA	Jacobs	TTAA	Jacobs	TTAA	Jacobs
06:00:00	1406	1447	1556	1594	3075	3014	3235	3159
07:00:00	2794	2905	3073	3233	3607	3555	3734	3735
08:00:00	3269	3303	3482	3703	3439	3410	3656	3718
09:00:00	2706	2629	3278	2970	3084	2856	3476	2873
AM Total	**8769**	**8837**	**9833**	**9906**	**10130**	**9821**	**10866**	**10326**
10:00:00	2779	2618	2937	2742	2957	2559	2884	2617
11:00:00	2565	2565	2663	2657	2454	2414	2513	2508
12:00:00	2590	2600	2685	2693	2728	2707	2843	2827
13:00:00	2847	2826	2946	2912	2774	2770	2874	2864
14:00:00	2944	2942	3053	3049	3022	3036	3154	3166
15:00:00	2701	2592	2798	2725	2668	2626	2834	2739
IP Total	**16426**	**16143**	**17082**	**16778**	**16603**	**16112**	**17102**	**16721**
16:00:00	3472	3448	3514	3716	3195	3176	3478	3381
17:00:00	3624	3591	3611	3818	3249	3310	3774	3822
18:00:00	3524	3345	3688	3406	3209	3325	3752	3414
PM Total	**10620**	**10384**	**10813**	**10940**	**9653**	**9811**	**11004**	**10617**
19:00:00	904	383	1343	475	893	593	487	367
Total	38125	37194	40627	39693	40354	39351	42694	41190

A904 - After Echline Corner

	Eastbound				Westbound			
	Do Min		Scheme		Do Min		Scheme	
Time	TTAA	Jacobs	TTAA	Jacobs	TTAA	Jacobs	TTAA	Jacobs
06:00:00	473	500	450	475	400	411	335	364
07:00:00	848	823	790	798	522	550	463	491
08:00:00	816	792	747	744	561	547	453	491
09:00:00	647	632	565	595	515	451	451	399
AM Total	**2311**	**2247**	**2102**	**2137**	**1598**	**1548**	**1367**	**1381**
10:00:00	496	494	483	479	546	467	493	429
11:00:00	465	467	448	450	463	454	422	419
12:00:00	490	487	465	472	503	497	454	457
13:00:00	502	511	482	490	498	501	452	457
14:00:00	539	539	506	525	547	547	490	501
15:00:00	483	436	456	426	675	660	628	619
IP Total	**2975**	**2934**	**2840**	**2842**	**3232**	**3126**	**2939**	**2882**
16:00:00	616	546	575	527	815	810	776	781
17:00:00	725	562	653	533	895	888	776	864
18:00:00	695	481	634	468	812	794	679	725
PM Total	**2036**	**1589**	**1862**	**1528**	**2522**	**2492**	**2231**	**2370**
19:00:00	54	46	158	43	200	167	96	87
Total	7849	7316	7412	7025	7952	7744	6968	7084

2017 Flow Comparisons - TTAA v Jacobs

B924 Bo'Ness Road

	Northbound				Southbound			
	Do Min		Scheme		Do Min		Scheme	
Time	TTAA	Jacobs	TTAA	Jacobs	TTAA	Jacobs	TTAA	Jacobs
06:00:00	54	63	111	121	78	86	112	120
07:00:00	93	95	178	175	130	131	192	180
08:00:00	81	71	147	149	128	129	178	173
09:00:00	59	60	117	98	96	94	133	134
AM Total	**233**	**226**	**442**	**422**	**354**	**354**	**503**	**487**
10:00:00	83	79	121	112	101	103	134	129
11:00:00	77	72	111	112	98	100	129	129
12:00:00	76	80	124	120	107	109	136	143
13:00:00	81	87	131	126	103	106	137	140
14:00:00	90	90	138	144	109	112	135	139
15:00:00	76	71	121	122	82	92	122	127
IP Total	**483**	**479**	**746**	**736**	**600**	**622**	**793**	**807**
16:00:00	90	93	148	157	113	118	169	177
17:00:00	105	102	174	195	120	130	181	193
18:00:00	90	82	171	160	106	110	196	180
PM Total	**285**	**277**	**493**	**512**	**339**	**358**	**546**	**550**
19:00:00	11	12	23	15	3	4	10	6
Total	1066	1057	1815	1806	1374	1424	1964	1970

A90 After M9 Spur

	Eastbound				Westbound			
	Do Min		Scheme		Do Min		Scheme	
Time	TTAA	Jacobs	TTAA	Jacobs	TTAA	Jacobs	TTAA	Jacobs
06:00:00	1191	1243	1135	1217	431	518	442	529
07:00:00	1655	1624	1544	1607	930	1067	937	1103
08:00:00	1693	1639	1610	1688	1087	1153	1100	1206
09:00:00	1470	1409	1540	1378	934	823	941	843
AM Total	**4818**	**4672**	**4694**	**4673**	**2951**	**3043**	**2978**	**3152**
10:00:00	1011	856	938	845	1118	912	1176	920
11:00:00	841	827	825	816	894	867	914	912
12:00:00	858	855	852	854	942	938	954	953
13:00:00	889	899	883	880	982	986	997	994
14:00:00	971	971	958	961	1069	1071	1087	1090
15:00:00	970	920	940	919	1208	1198	1192	1244
IP Total	**5540**	**5328**	**5396**	**5275**	**6213**	**5972**	**6320**	**6113**
16:00:00	1166	1113	1123	1121	1795	1866	1791	1919
17:00:00	1207	1164	1226	1265	1781	1859	1702	1901
18:00:00	1205	1179	1236	1191	1666	1527	1434	1609
PM Total	**3578**	**3456**	**3585**	**3577**	**5242**	**5252**	**4927**	**5429**
19:00:00	338	260	243	161	88	98	69	138
Total	15465	14959	15053	14903	14925	14883	14736	15361

2017 Flow Comparisons - TTAA v Jacobs

M9 Spur

	Northbound				Southbound			
	Do Min		Scheme		Do Min		Scheme	
Time	TTAA	Jacobs	TTAA	Jacobs	TTAA	Jacobs	TTAA	Jacobs
06:00:00	723	738	880	888	1469	1443	1779	1621
07:00:00	1437	1425	1782	1759	1741	1742	2117	1999
08:00:00	1747	1678	2163	2083	1506	1661	2009	1968
09:00:00	1356	1328	1701	1622	1491	1430	1950	1562
AM Total	**4540**	**4431**	**5646**	**5464**	**4738**	**4833**	**6076**	**5529**
10:00:00	1539	1551	1641	1664	1693	1491	1740	1585
11:00:00	1464	1469	1567	1559	1442	1432	1557	1548
12:00:00	1505	1509	1604	1615	1626	1631	1771	1765
13:00:00	1687	1673	1783	1766	1633	1633	1781	1765
14:00:00	1745	1744	1849	1843	1781	1809	1955	1963
15:00:00	1489	1340	1618	1471	1491	1449	1699	1636
IP Total	**9429**	**9286**	**10062**	**9918**	**9666**	**9445**	**10503**	**10262**
16:00:00	1996	1709	1996	1889	1725	1690	2038	1938
17:00:00	1762	1681	1996	1842	1798	1805	2254	2223
18:00:00	1569	1351	1874	1519	1785	1803	2183	1990
PM Total	**5327**	**4741**	**5866**	**5250**	**5308**	**5298**	**6475**	**6151**
19:00:00	194	159	301	182	522	386	377	267
Total	20213	19355	22755	21702	21703	21405	25210	23830